

## Supporting information

### In situ cross-linked vinylphosphonic acid-modified aminosilicon oxide gel electrolyte for proton exchange membrane fuel cells

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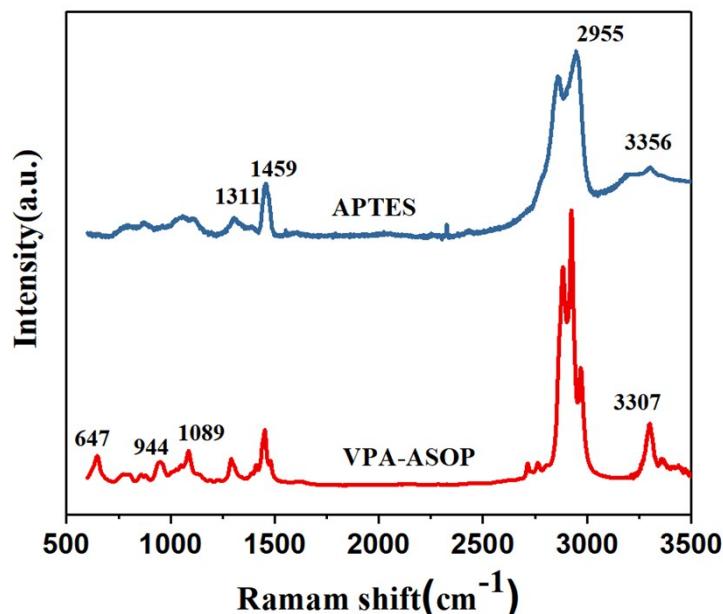
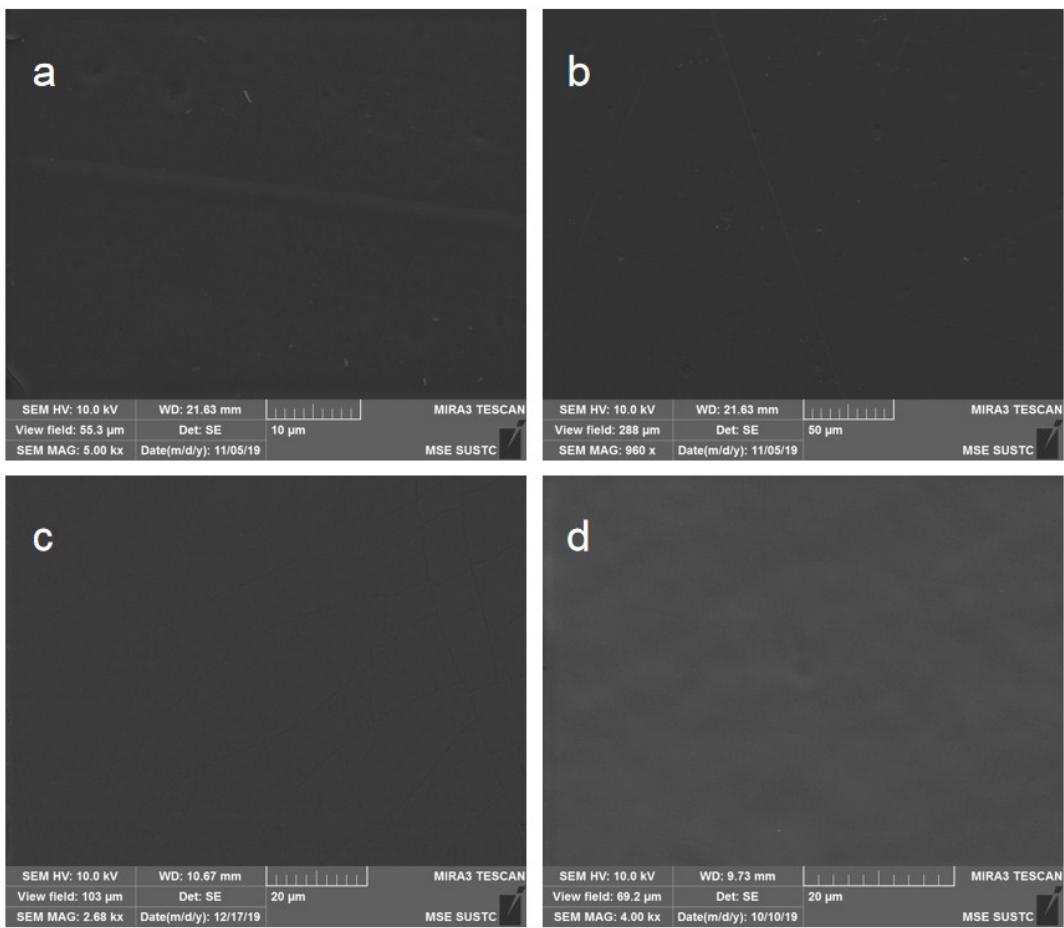
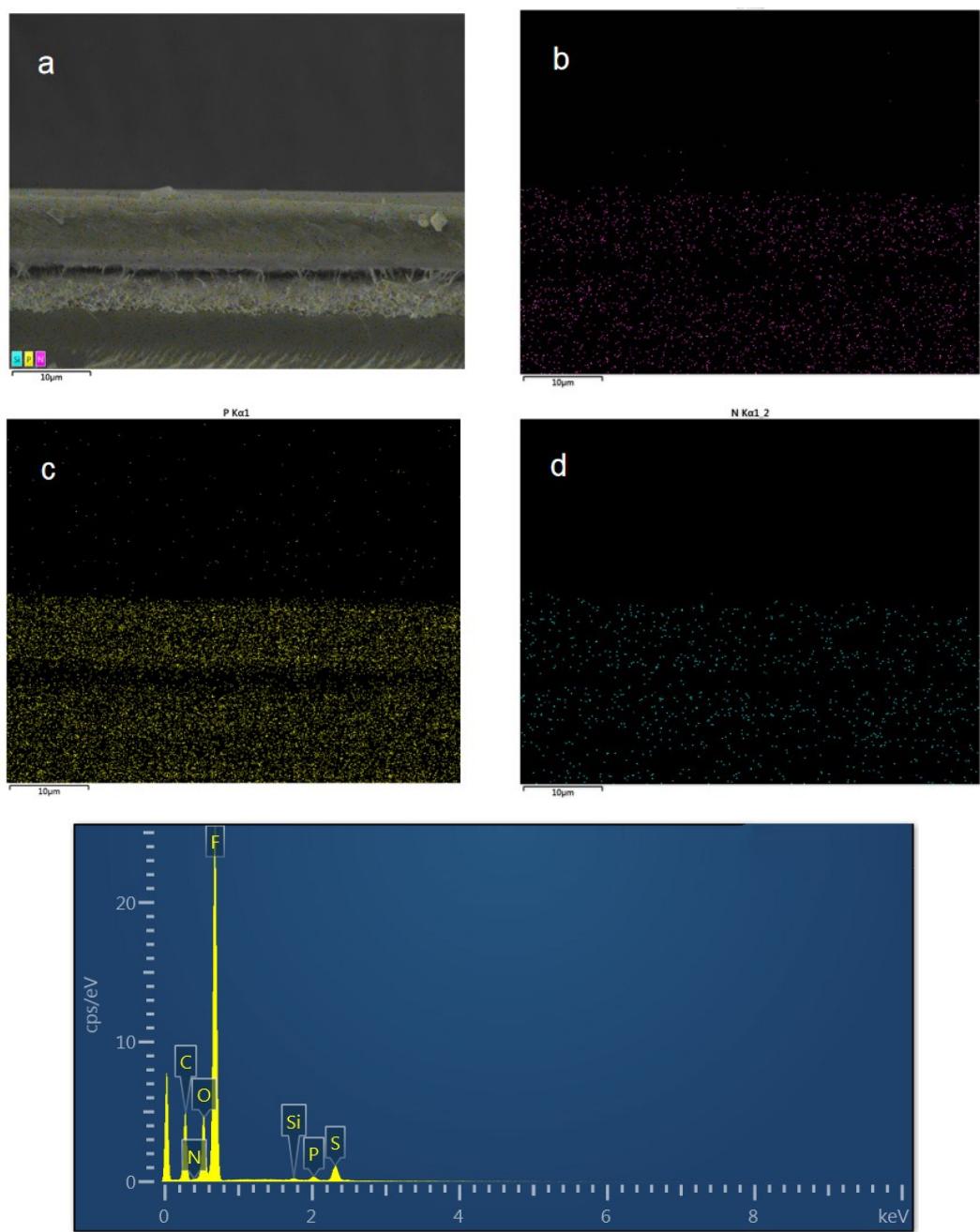


Fig.S1 Raman spectra of the APES and VPA-ASOP.



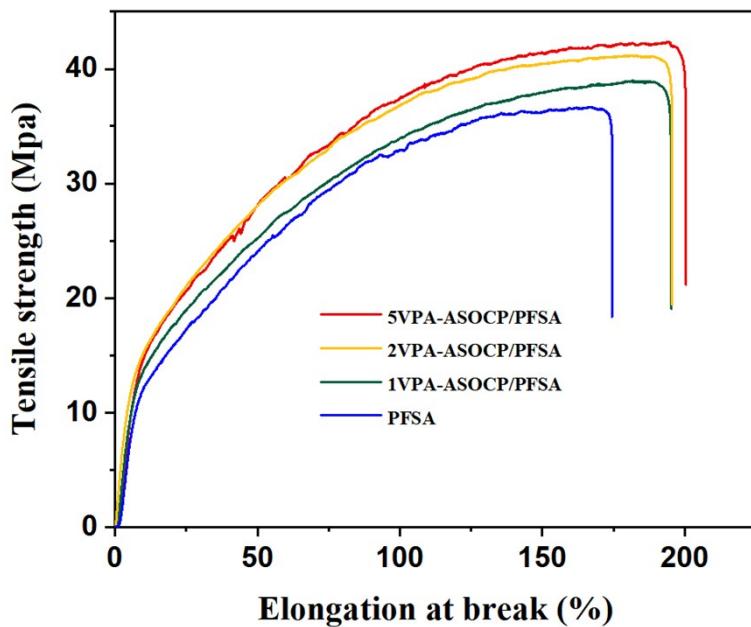
**Fig.S2 SEM images of (a) PFSA membrane, (b)1VPA-ASOCP/PFSA, (c) 2VPA-ASOCP/PFSA, (d) 5VPA-A SOCP/PFSA.**



**Fig. S3 EDS mapping for 2VPA-ASOCP/PSA membrane.**

**Table 1 Elements content of VPA-ASOCP/PFSA composite membranes based on EDS**

elements	wt%	wt% Sigma
C	24.64	0.26
N	0.14	0.02
O	11.24	0.16
F	59.69	0.36
Si	0.30	0.03
P	0.41	0.05
S	3.58	0.08
total	100.00	



**Fig. S4 Stress-strain curves of PFSA membrane and VPA-ASOCP/PFSA composite membranes.**

**Table S2 Mechanical properties of PFSA and PHEDP/PFSA composite membranes**

Membrane	Young's modulus(Mpa)		Tensile strength ( Mpa )		Elongation at break ( % )	
	MD	TD	MD	TD	MD	TD
5VPA- ASOCP/PFSA	275.46±16.2 4	256.94±16.1 2	41.19±1.8 6	40.67±2.3 4	204.5±21.8 191.6±13.9	229.4±19.8 104.4±22.1
2VPA- ASOCP/PFSA	269.75±15.6 8	248.25±12.8 9	38.24±1.2 3	38.55±2.1 4	185.4±26.3 174.6±12.5	194.7±19.0 178.6±17.4
1VPA- ASOCP/PFSA	246.56±12.4 3	232.64±13.6 9	37.84±1.5 2	37.97±1.5 9	36.86±2.0 36.96±2.3	36.96±2.3
PFSA	220.35±14.8 3	222.74±12.2 8	41.19±1.8 1	40.67±2.3 2	204.5±21.8 191.6±13.9	229.4±19.8 104.4±22.1

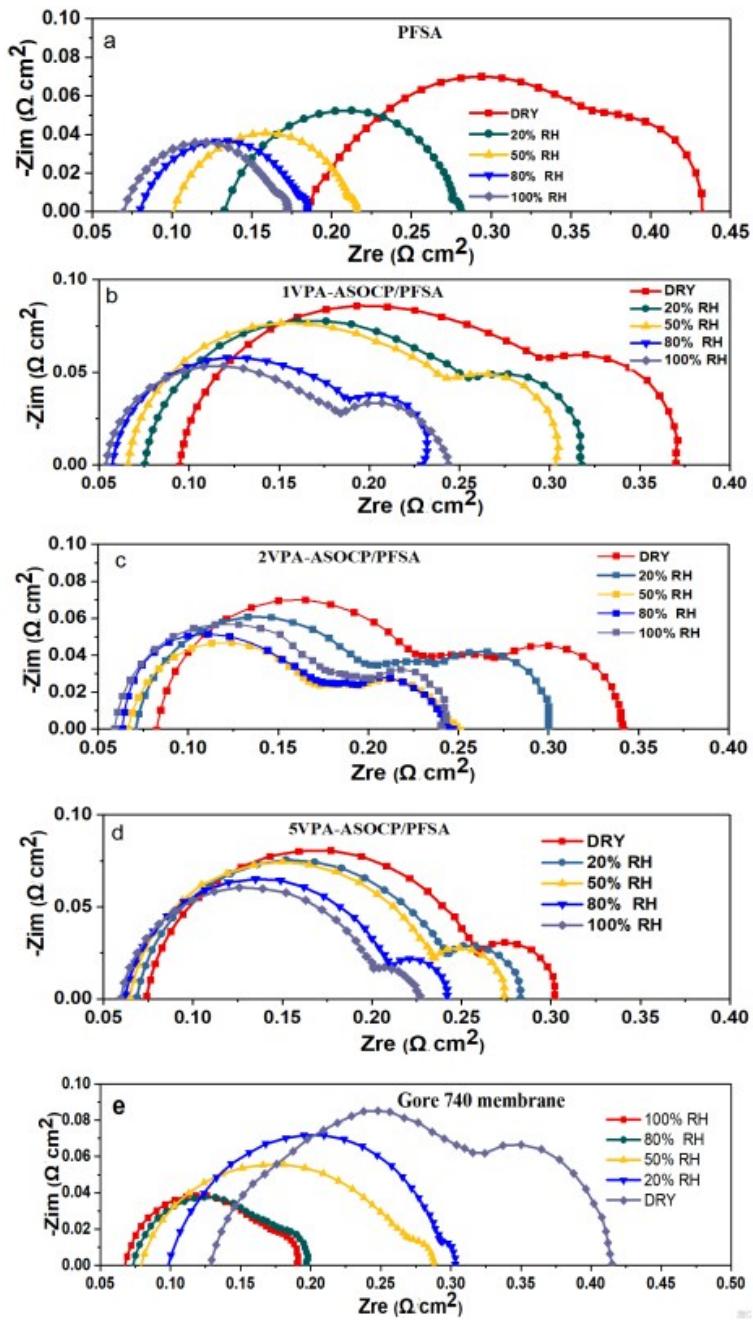
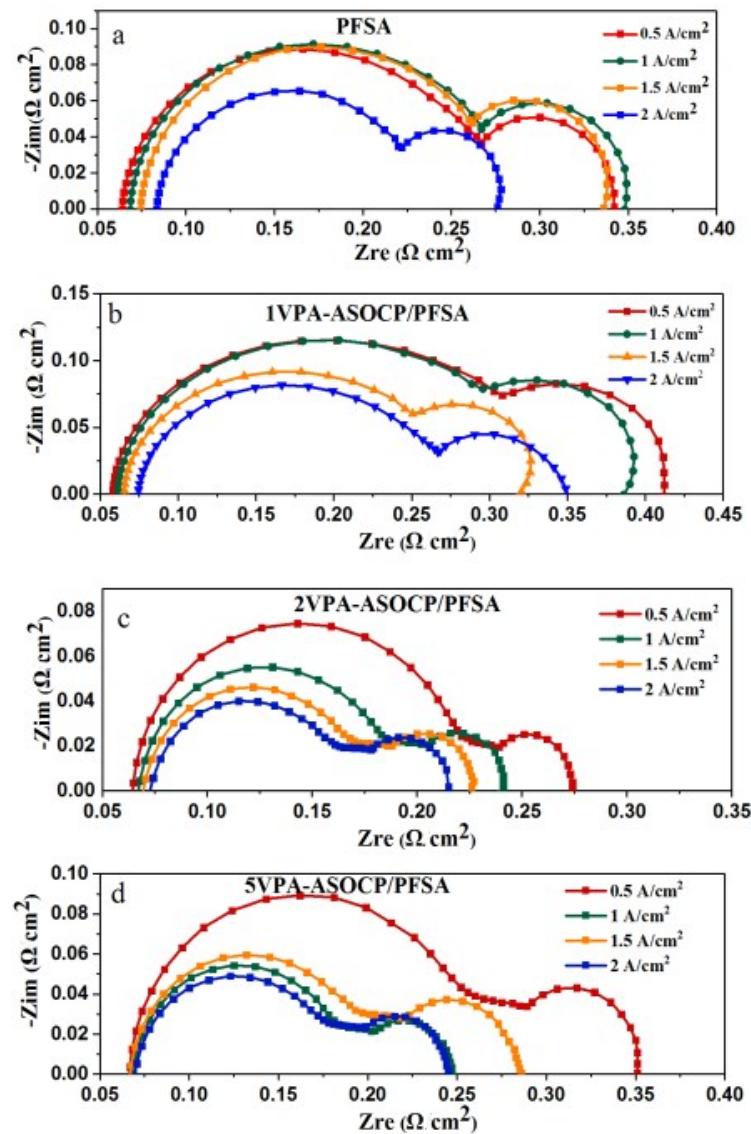


Fig. S5 EIS for the membranes: (a) PFSA, (b) 1VPA-ASOCP/PFSA, (c) 2VPA-ASOCP/PFSA, and (d) 5VPA-ASOCP/PFSA at  $1 \text{ A} \cdot \text{cm}^{-2}$  for various RHs.



**Fig. S6 EIS for the membranes: (a) PFSA, (b) 1VPA-ASOCP/PFSA, (c) 2VPA-ASOCP/PFSA, and (d) 5VPA-ASOCP/PFSA under 50% RH.**