

## Supporting Information

### **Time-Phase-Controlled Exsolution of FeCoNi Ternary Alloy Nanoparticles on Perovskite Anode Catalyst for Enhanced Dual-Functional Catalysis and Protection in Ammonia-Fueled Protonic Ceramic Fuel Cells**

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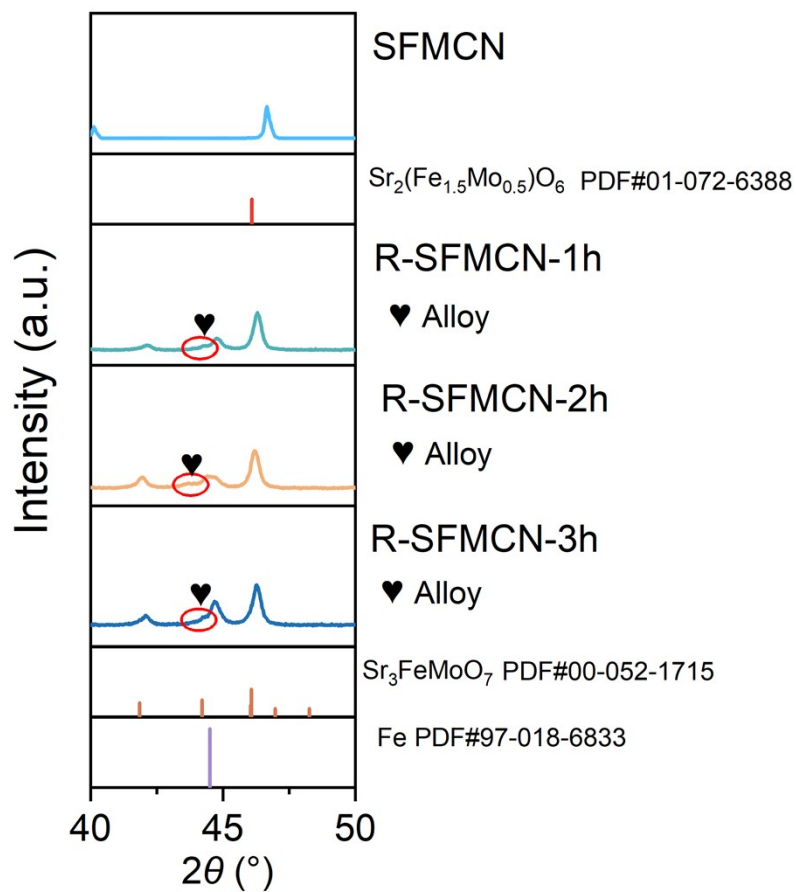


Figure S1. The enlarged view of XRD patterns.

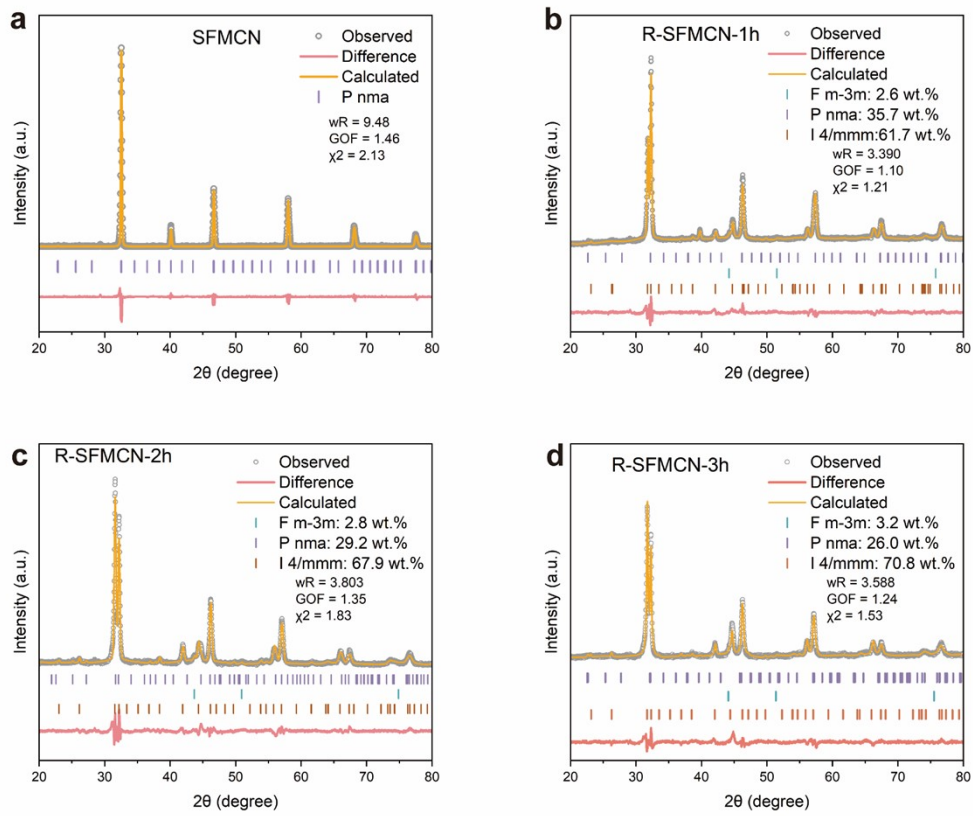


Figure S2. Rietveld refinement results of SFMCN and R-SFMCN samples.

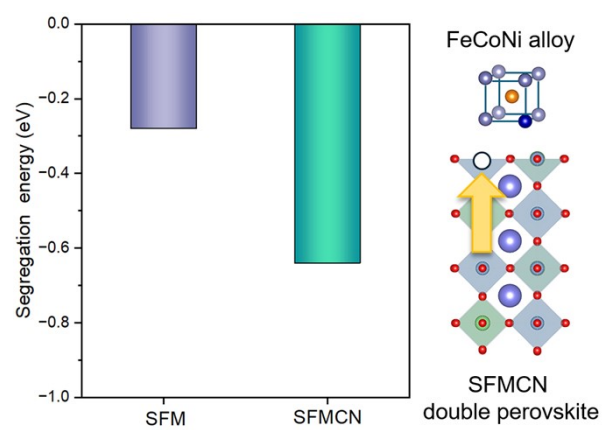


Figure S3. The segregation energies of Fe in SFM and SFMCN perovskites.

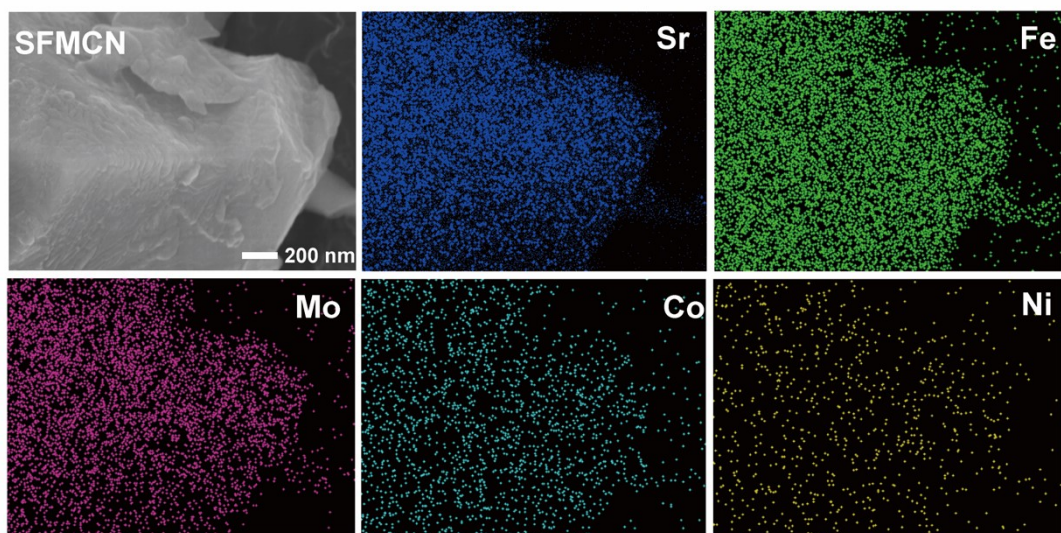


Figure S4. SEM images and EDS-mapping of prepared SFMCN powders.

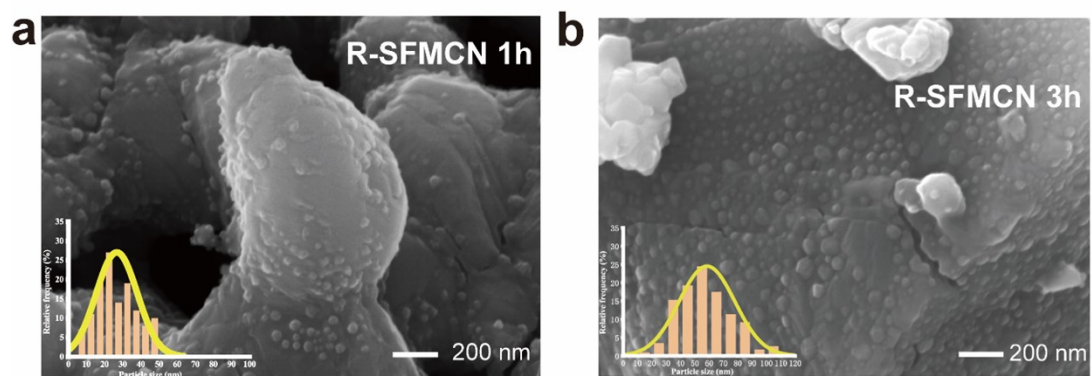


Figure S5. SEM results of SFMCN after (a) 1 hour and (b) 3 hours after reducing atmosphere.

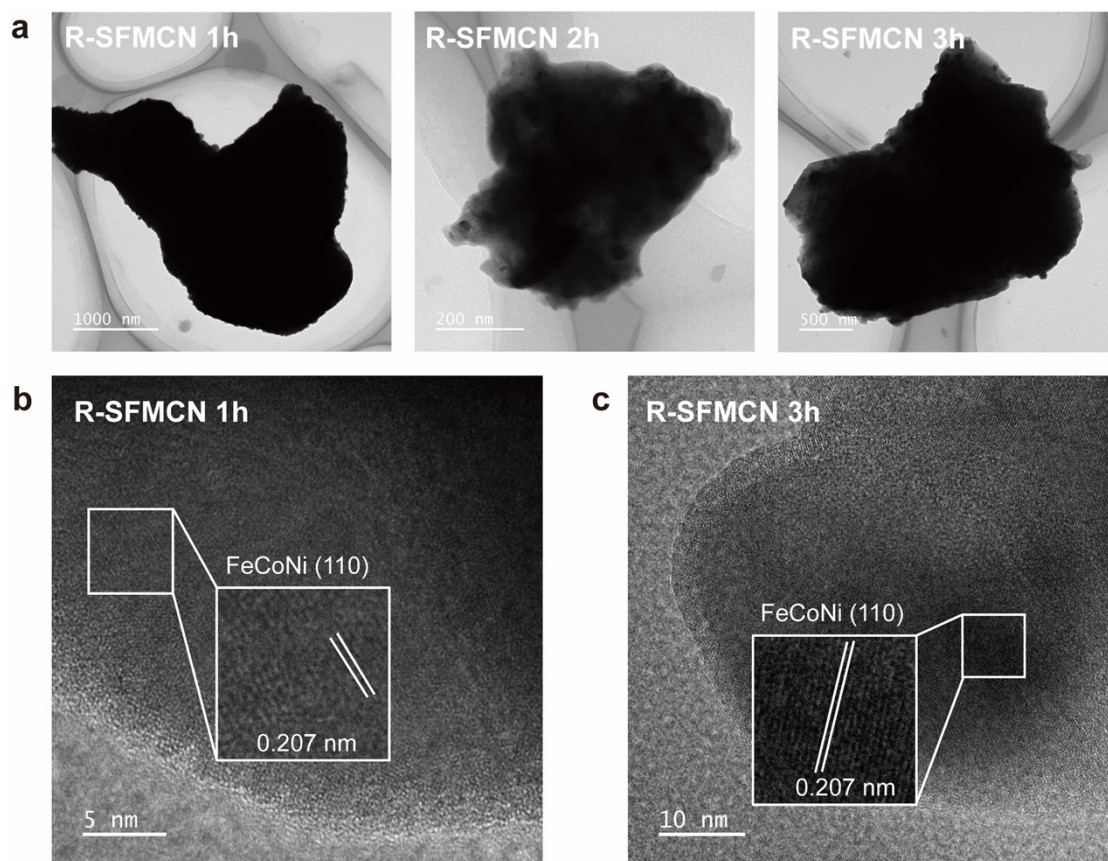


Figure S6. (a) TEM images of R-SFMCN- $x$  ( $x=1, 2, 3$ ) samples; TEM images with clear fringes of (b) R-SFMCN-1h and (c) R-SFMCN-3h.

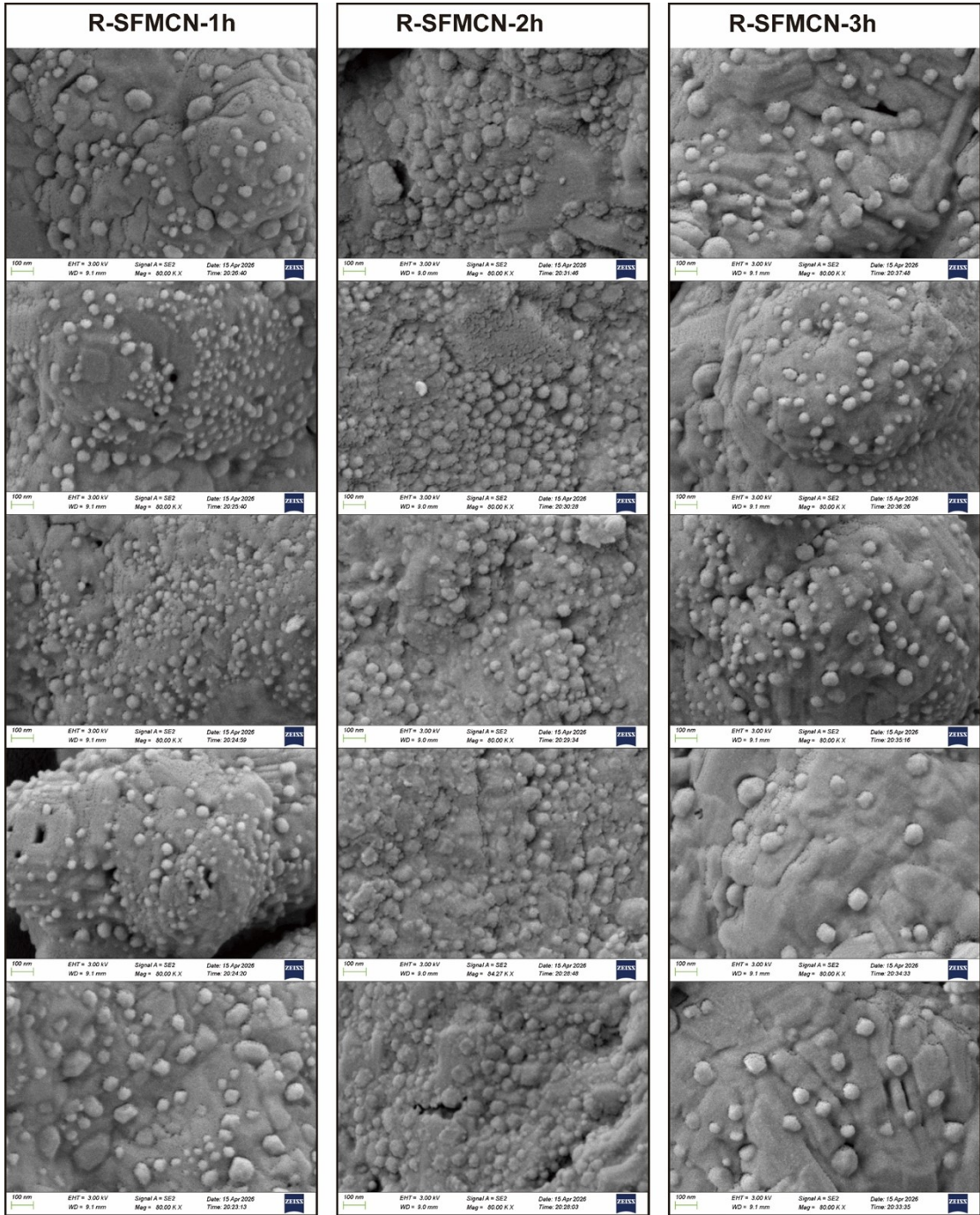


Figure S7. The SEM photographs used for TPB statistics.

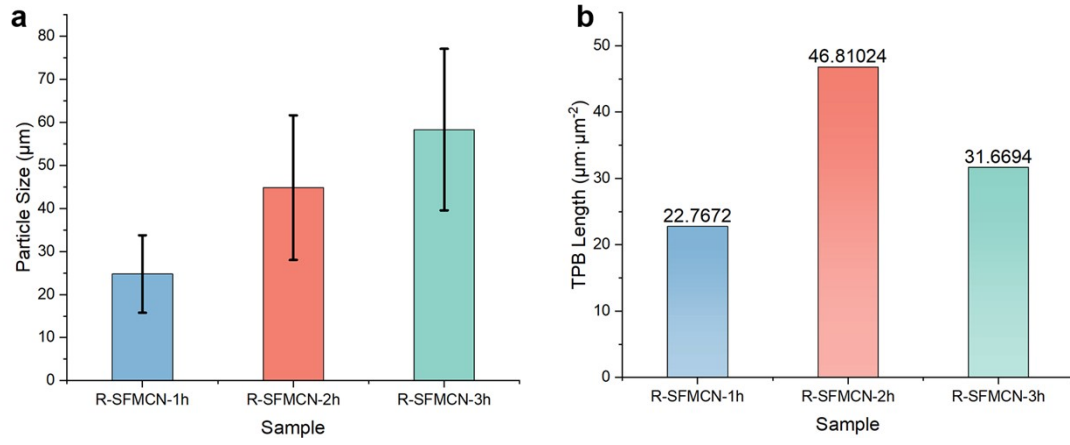


Figure S8. The TPB statistics results.

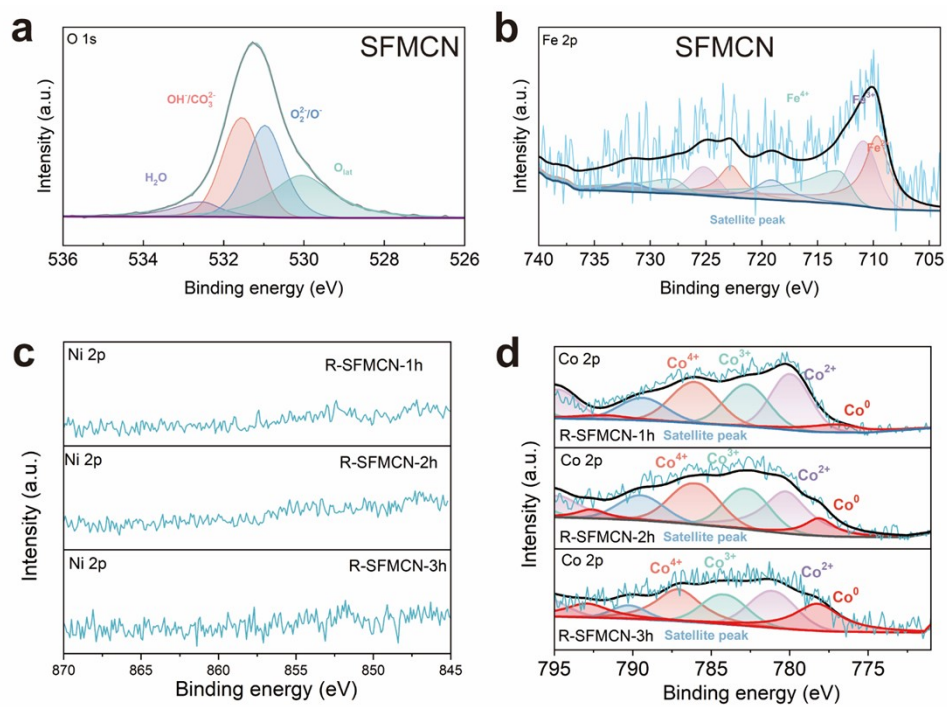


Figure S9. XPS spectra of (a) O 1s and (b) Fe 2p in SFMCN; XPS spectra of (c) Co 2p and (d) Ni 2p in R-SFMCN samples.

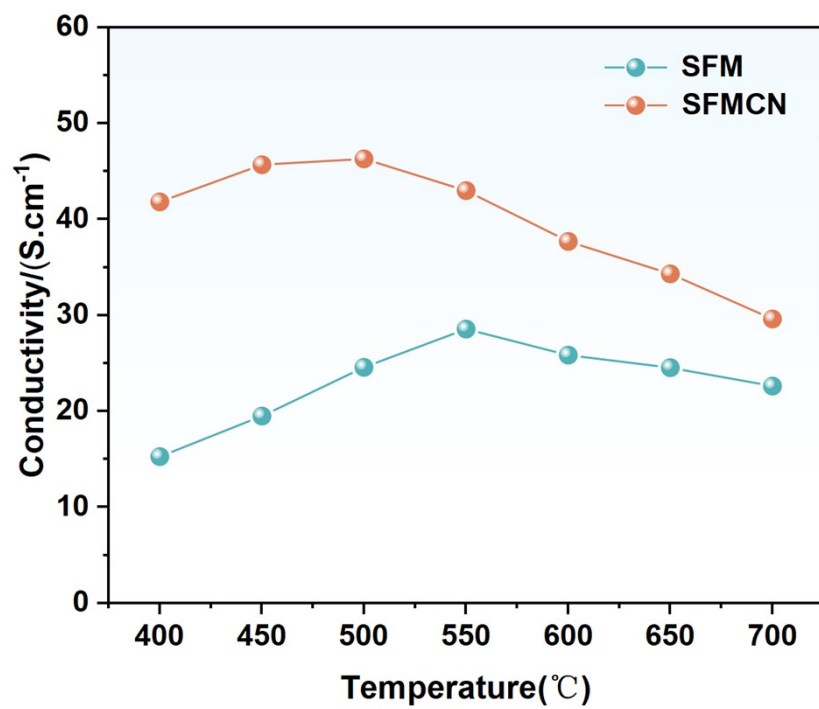


Figure S10. Total conductivity of SFM and SFMCN in air.

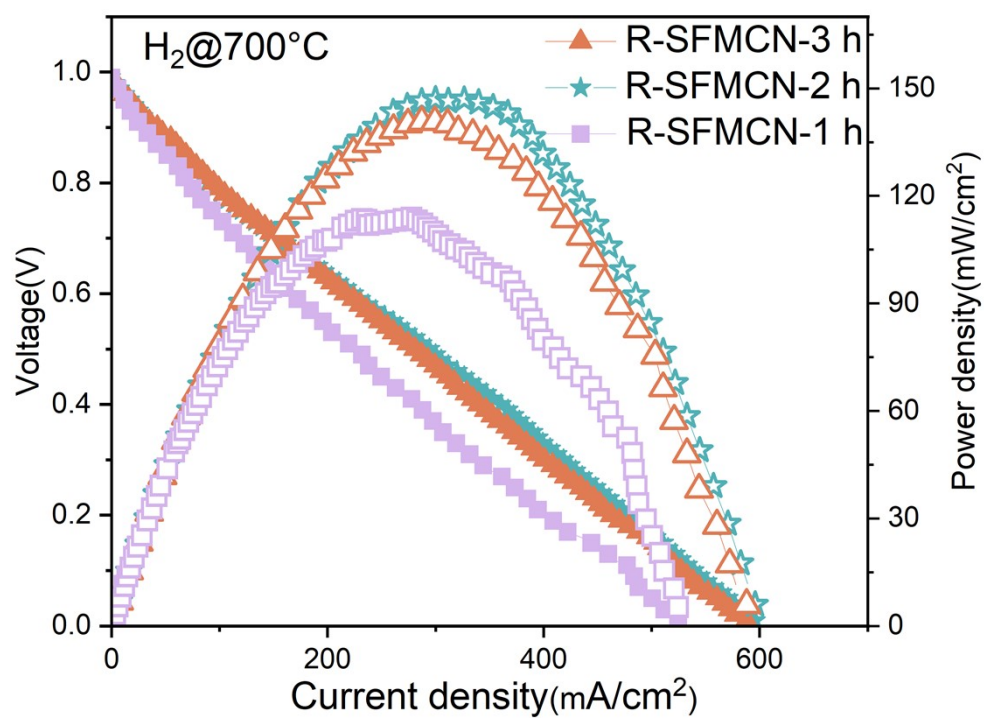


Figure S11. I-V-P plots of symmetrical cell with SFMCN ACL in  $\text{NH}_3$ .

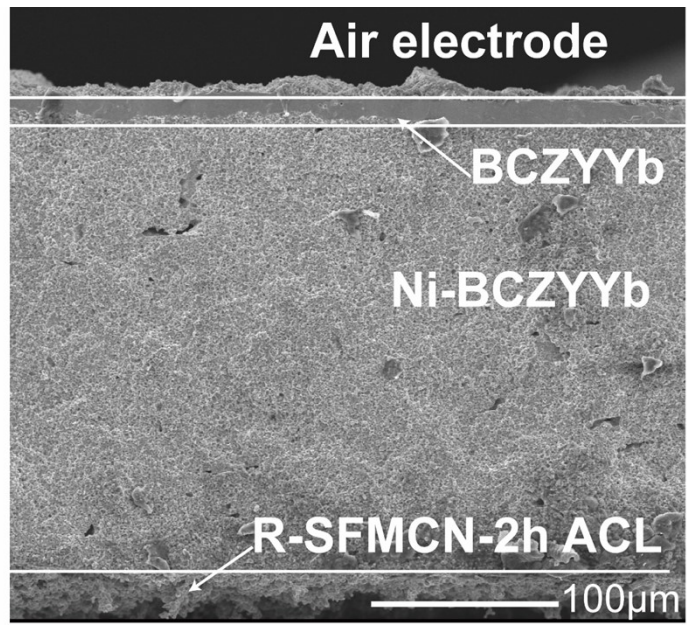


Figure S12. The SEM image of the cross-section of single cell with SFMCN ACL.

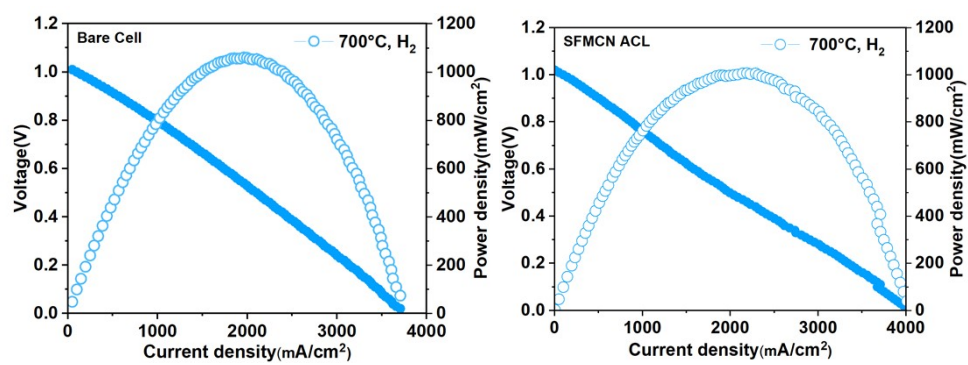


Figure S13. I-V-P plots of bare cell and single cell with R-SFMCN-2h ACL in H<sub>2</sub>.

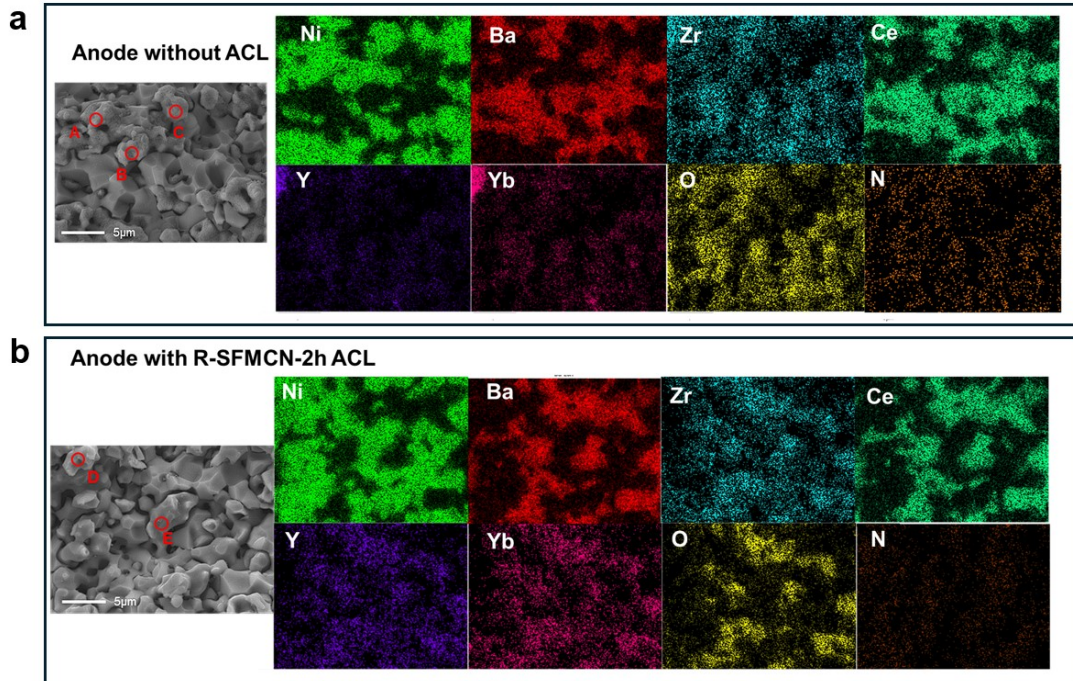


Figure S14. EDS mapping results of (a) anode without ACL and (b) anode with R-SFMCN-2h ACL after durability test.

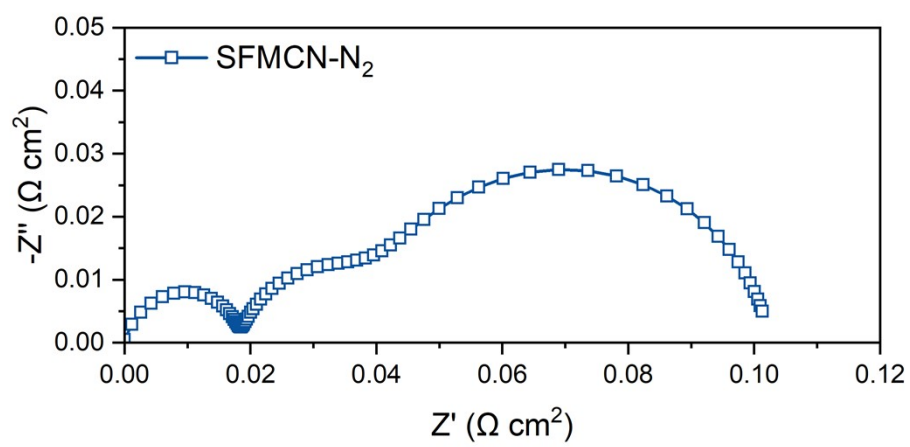


Figure S15. EIS plots of SFMCN in  $N_2$  atmosphere.

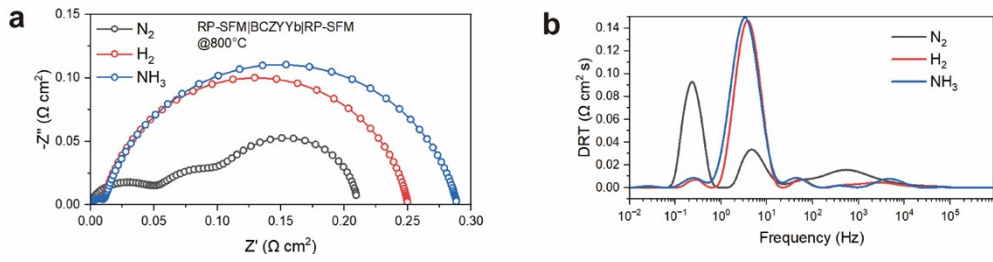


Figure S16. (a) EIS plots and (b) DRT curves of RP-SFM in different atmosphere.

Table S1 XRD refinement result of reduced SFMCN.

Sample	Space group	a (Å)	b (Å)	c(Å)	wR	GOF	$\chi^2$	wt.%
SFMCN	Pnma	5.4902	5.4896	7.7768	9.48	1.46	2.13	/
R-SFMCN-	Pnma	5.5683	5.5676	7.8637				35.7
1h	Fm-3m	3.5509	3.5509	3.5509	3.390	1.10	1.21	2.6
	I 4/mmm	3.9291	3.9291	20.2839				61.7
R-SFMCN-	Pnma	5.5599	5.5593	8.0969				29.2
2h	Fm-3m	3.5817	3.5817	3.5817	3.803	1.35	1.82	2.8
	I 4/mmm	3.9280	3.9280	20.4054				67.9
R-SFMCN-	Pnma	5.5741	5.5734	7.9243				26.0
3h	Fm-3m	3.5602	3.5602	3.5602	3.588	1.24	1.53	3.2
	I 4/mmm	3.9288	3.9288	20.429				70.8

Table S2 Fitting results of Fe 2p from XPS spectra

Sample	Fe 2p			
	Fe <sup>4+</sup>	Fe <sup>3+</sup>	Fe <sup>2+</sup>	Fe <sup>0</sup>
SFMCN	26.95%	33.98%	39.06%	0%
R-SFMCN-1h	10.85%	29.71%	57.14%	2.28%
R-SFMCN-2h	9.13%	36.54%	50.76%	3.55%
R-SFMCN-3h	23.42%	25.68%	45.04%	5.85%

Table S3 Fitting results of O 1s from XPS spectra

Sample	O 1s		
	O <sub>ads</sub> (OH <sup>-</sup> +O <sup>-</sup> /O <sub>2</sub> <sup>2-</sup> +H <sub>2</sub> O)	O <sub>lat</sub>	O <sub>c</sub> /O <sub>lat</sub>
SFMCN	73.18%	26.82%	1.96
R-SFMCN-1h	75.54%	24.46%	3.08
R-SFMCN-2h	78.64%	21.36%	3.68
R-SFMCN-3h	81.59%	18.41%	4.43

Table S4. point EDS scanning results of SEM samples.

Sample Point	Without ACL			With ACL	
Elements	A Atom%	B Atom%	C Atom%	D Atom%	E Atom%
N	5.20	2.30	6.58	0.00	0.00
O	18.10	19.90	27.74	10.06	4.38
Ni	74.67	76.58	64.61	87.64	93.85
Y	0.13	0.06	0.00	0.26	0.00
Zr	0.08	0.04	0.00	0.23	0.00
Ba	0.66	0.35	0.50	0.84	0.74
Ce	0.39	0.39	0.29	0.56	0.62
Yb	1.30	0.77	0.39	0.40	0.41