Supporting information

Exsolved Nanoparticles Decorated Double Perovskites as High-Performance Anodes for Direct-Ammonia Solid Oxide Fuel Cells

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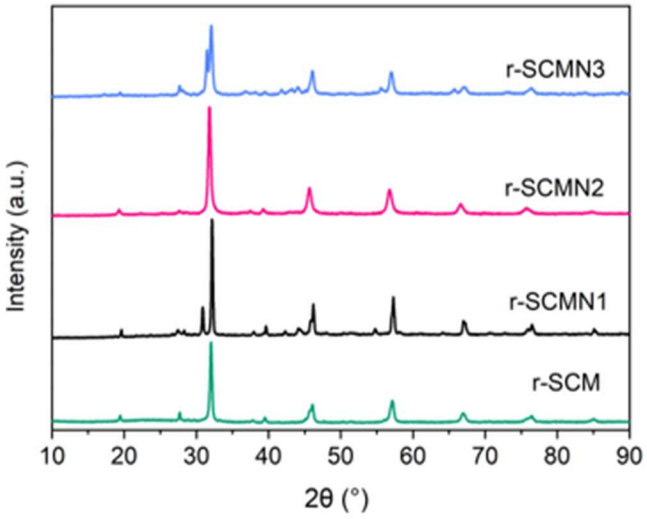


Figure S1. XRD patterns of reduced SCMN and SCM samples.

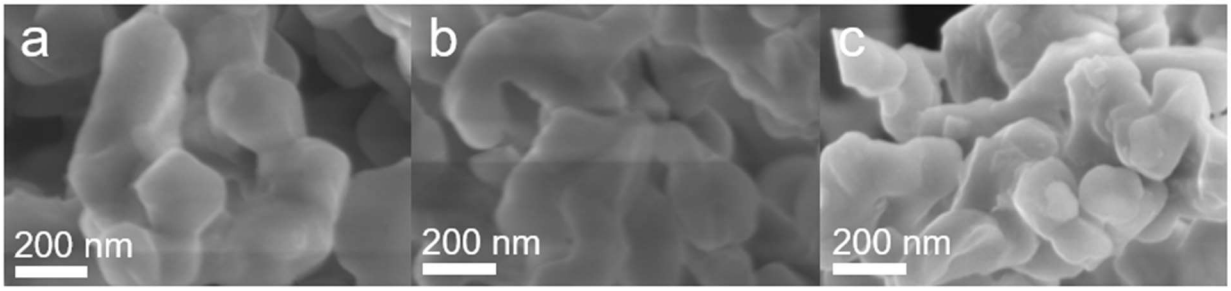
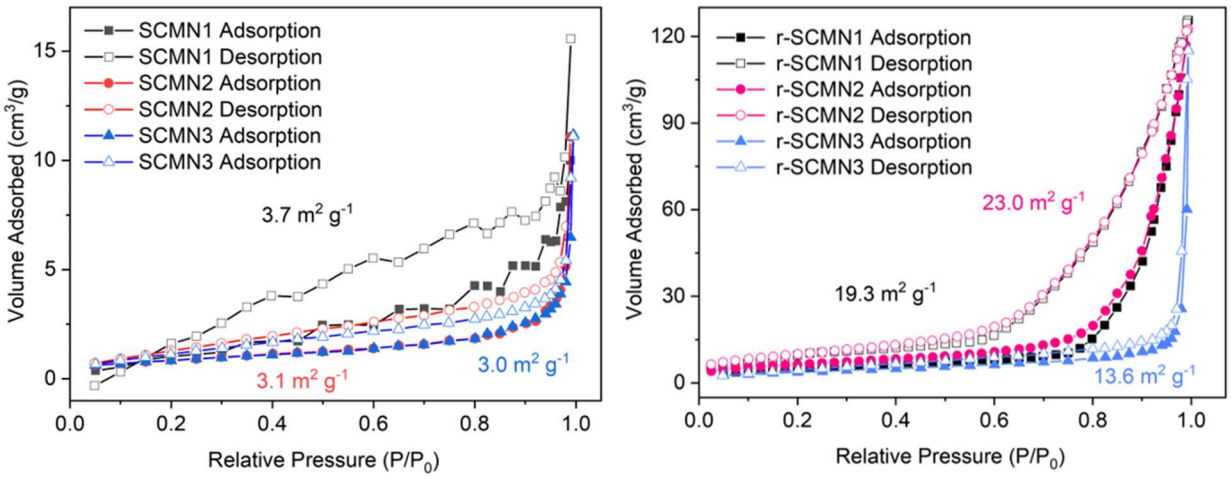


Figure S2. SEM images of (**a**) SCMN1, (**b**) SCMN2 and (**c**) SCMN3 samples.



(a) **(b)**

Figure S3. Nitrogen adsorption/desorption isotherms of SCMN1, SCMN2 and SCMN3 samples (**a**) before and (**b**) after the reduction.

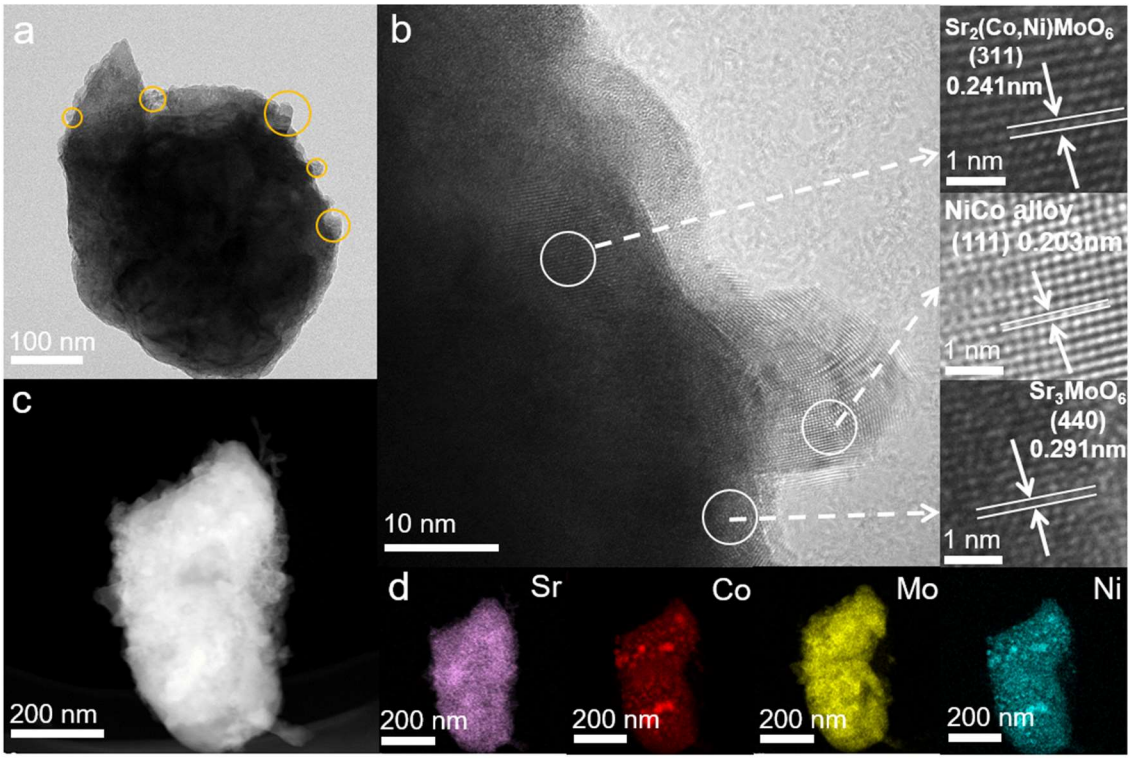


Figure S4. (**a**) TEM, (**b**) HR-TEM, (**c**) STEM and (**d**) EDX mapping images of r-SCMN1 sample.

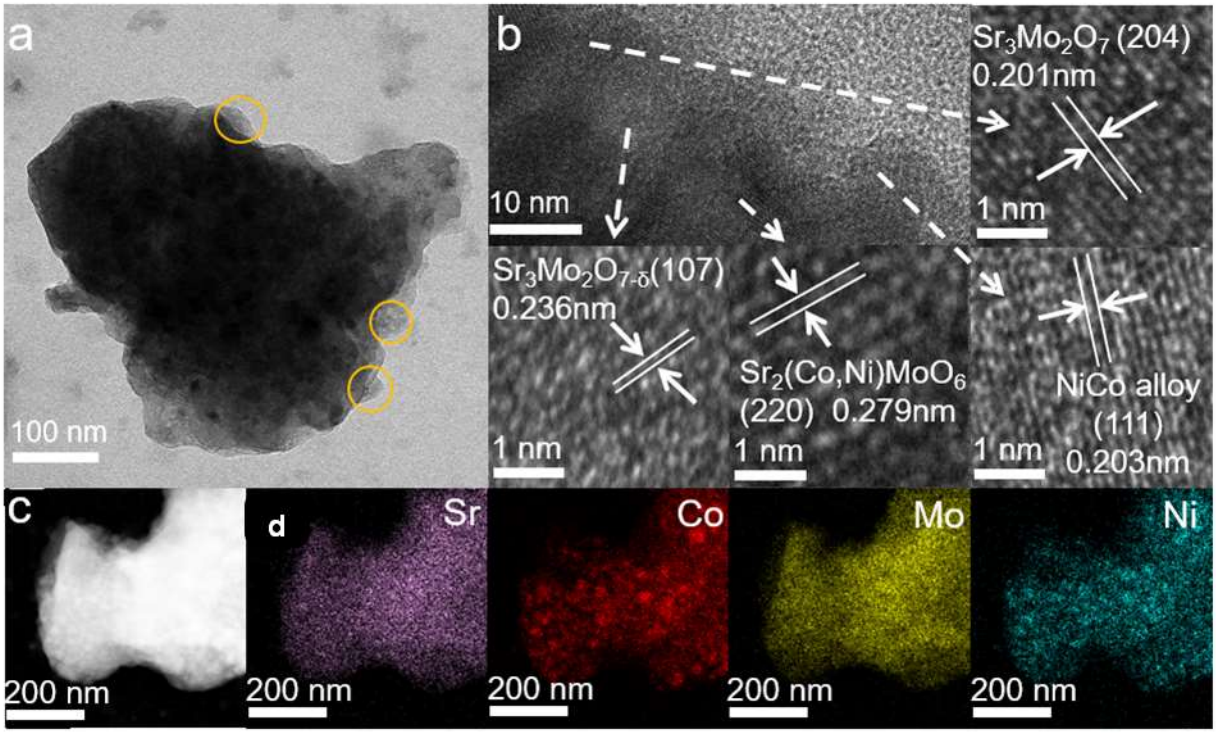


Figure S5. (**a**) TEM, (**b**) HR-TEM, (**c**) STEM and (**d**) EDX mapping images of r-SCMN3 sample.

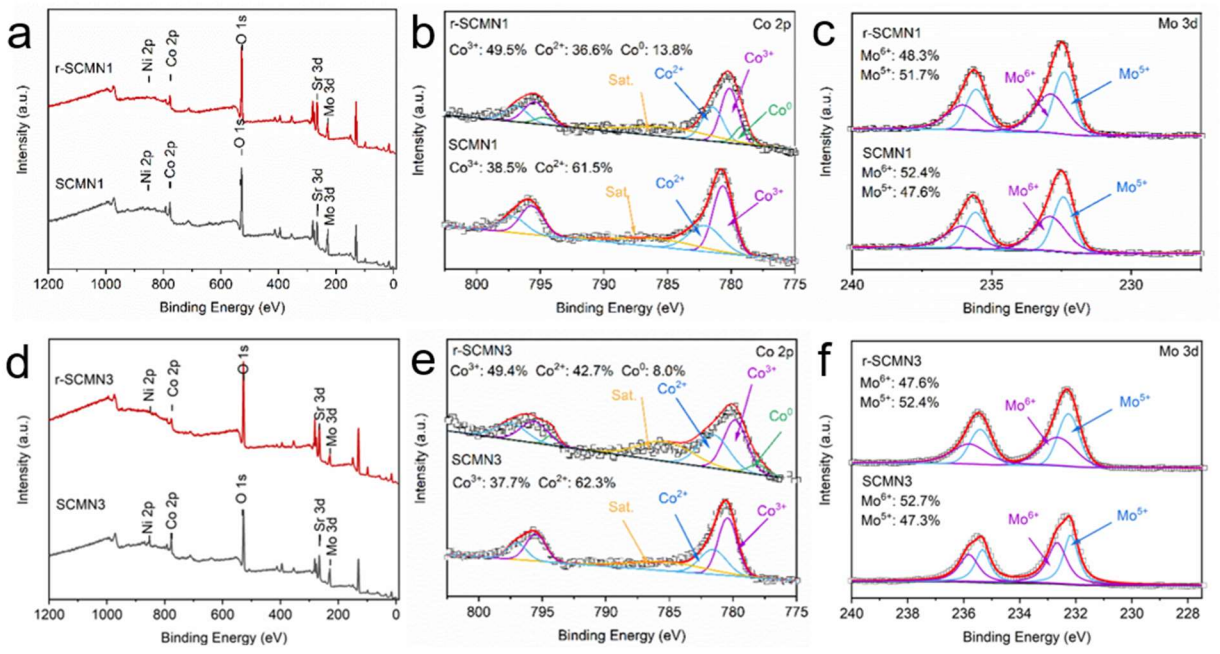


Figure S6. XPS spectra of SCMN1 and SCMN3 samples before and after the reduction: (**a**,**d**) XPS survey, (**b**,**e**) Co 2p and (**c**,**f**) Mo 3d.

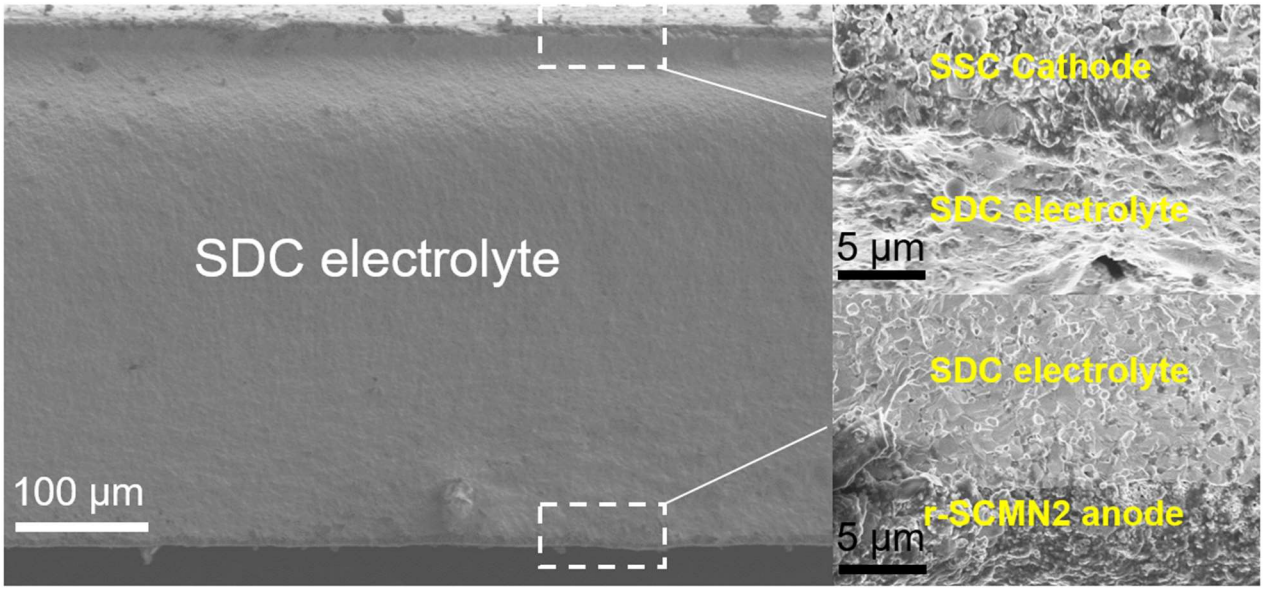


Figure S7. Typical cross-sectional SEM images of a fuel cell with r-SCMN2 anode.

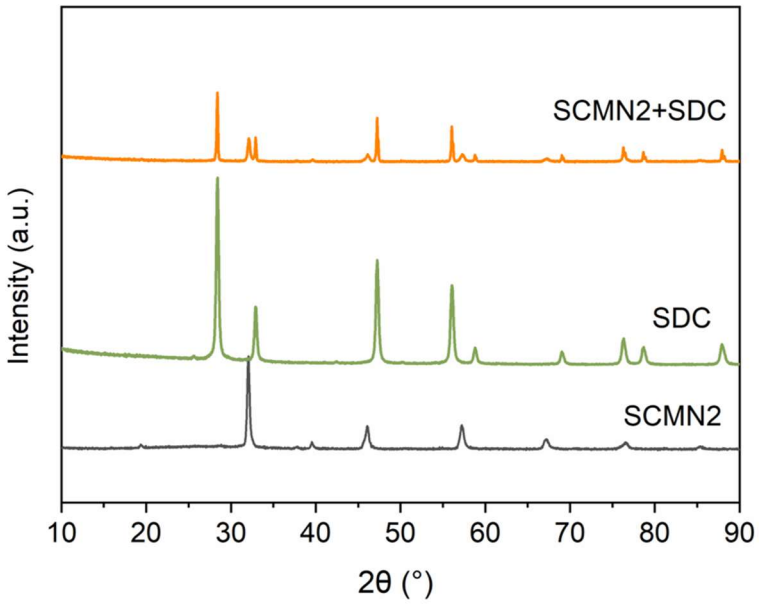


Figure S8. XRD patterns of SDC, SCMN2 and SDC+SCMN2 composite (1:1, weight ratio) prepared by physical mixing after a calcination at 1000 °C for 2 h in air.

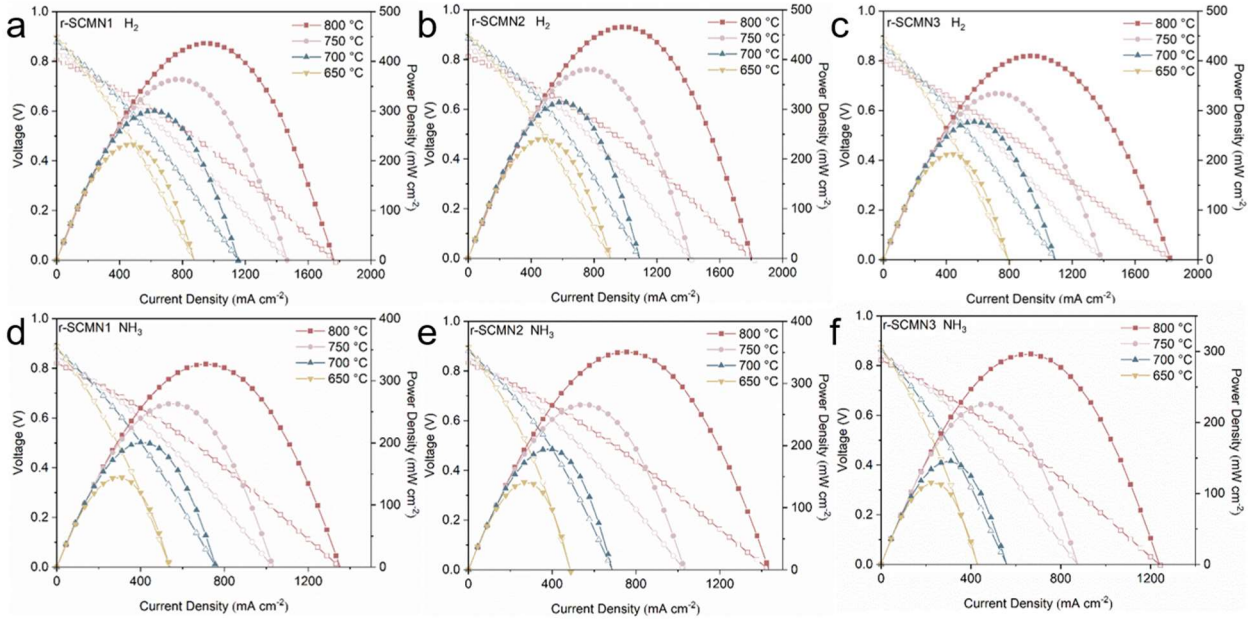


Figure S9. *I-V* and *I-P* curves of SOFCs with (**a**,**d**) r-SCMN1, (**b**,**e**) r-SCMN2 and (**c**,**f**) r-SCMN3 anodes operated on H_2 (**a**-**c**) and NH_3 (**d**-**f**) fuels at 650-800 °C.

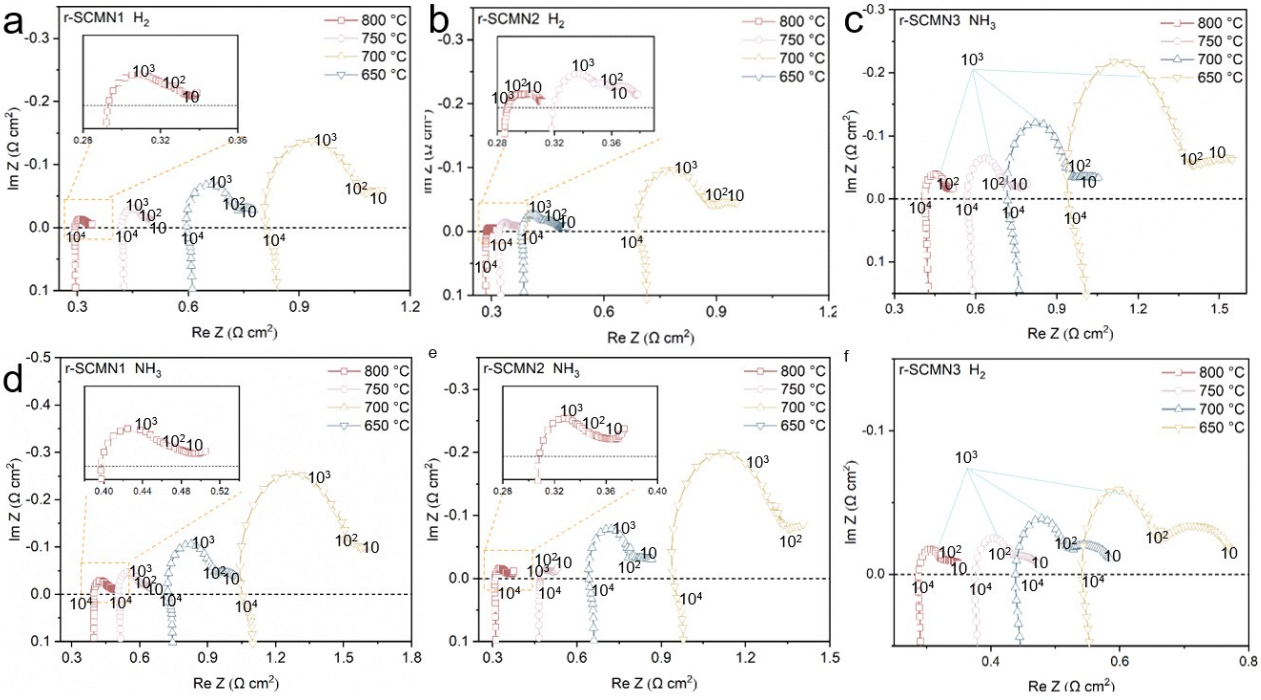


Figure S10. EIS spectra of SOFCs with (**a**,**d**) r-SCMN1, (**b**,**e**) r-SCMN2 and (**c**,**f**) r-SCMN3 anodes operated on H_2 (**a**-**c**) and NH_3 (**d**-**f**) fuels at 650-800 °C.

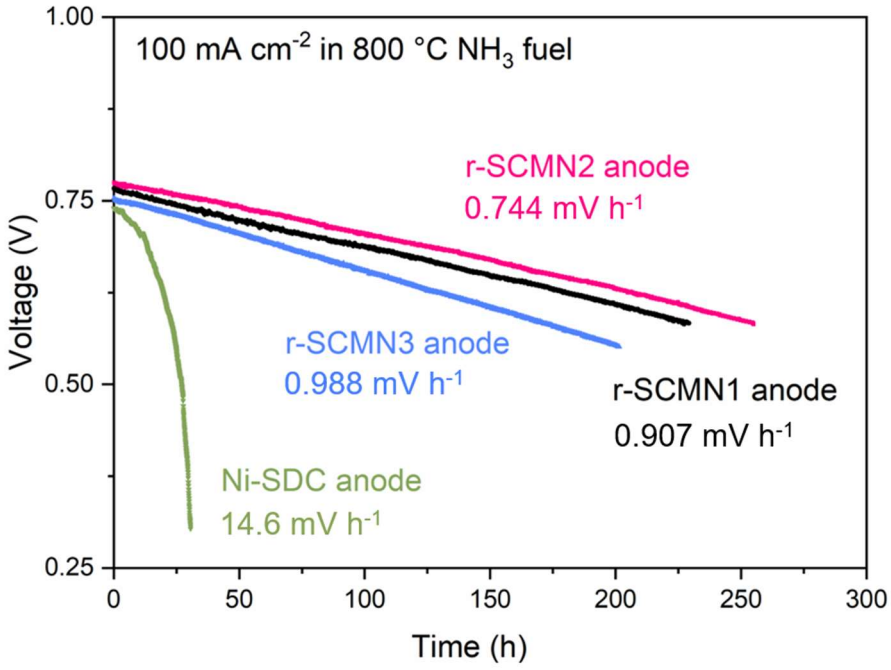


Figure S11. Operational stability of single cells with r-SCMN1, r-SCMN2, r-SCMN3 and Ni-SDC anodes operated on NH_3 fuel under a certain current density of 100 mA cm^{-2} at 800 °C.

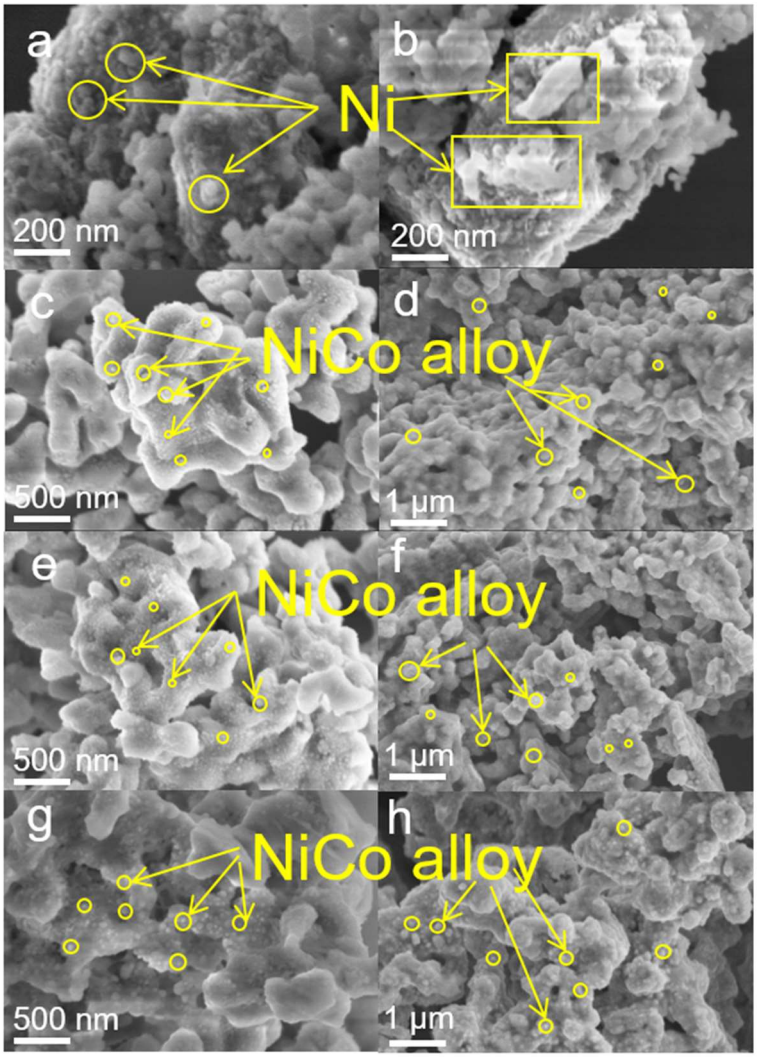


Figure S12. SEM images of (**a**,**b**) Ni-SDC, (**c**,**d**) r-SCMN1, (**e**,**f**) r-SCMN2 and (**g**,**h**) r-SCMN3 anodes before (**a**,**c**,**e**,**g**) and after (**b**,**d**,**f**,**h**) the treatment in NH_3 fuel at 800 °C for 30 h.

Table S1. PPDs comparison of the single cells with r-SCMN anodes at different temperatures in H_2 and NH_3 fuels.

Anode	Fuel	PPD (mW cm^{-2})			
		800 °C	750 °C	700 °C	650 °C
r-SCMN1	H_2	436	363	300	232
	NH_3	327	262	200	144
r-SCMN2	H_2	465	380	314	239
	NH_3	350	266	194	141
r-SCMN3	H_2	409	334	277	212
	NH_3	296	225	145	115

Table S2. R_p values of the single cells with r-SCMN anodes at different temperatures in H_2 and NH_3 fuels.

Anode	Fuel	R_p (Ω cm^2)			
		800 °C	750 °C	700 °C	650 °C
r-SCMN1	H_2	0.036	0.068	0.126	0.225
	NH_3	0.063	0.095	0.203	0.437
r-SCMN2	H_2	0.027	0.041	0.063	0.198
	NH_3	0.041	0.054	0.158	0.410
r-SCMN3	H_2	0.045	0.063	0.090	0.234
	NH_3	0.081	0.135	0.230	0.446
Ni-SDC	H_2	0.117	0.185	0.279	0.369
	NH_3	0.140	0.207	0.342	0.644

Table S3. PPDs comparison of DA-SOFCs with r-SCMN1, r-SCMN2 and r-SCMN3 anodes developed in this work and other representative anodes reported in the literature.

Anode	Electrolyte/Cathode	Electrolyte thickness (μm)	PPD (mW cm^{-2}) at 800 °C	Ref.
r-SCMN1	**SDC/SSC**	**350**	**327**	**This work**
r-SCMN2	**SDC/SSC**	**350**	**350**	**This work**
r-SCMN3	**SDC/SSC**	**350**	**296**	**This work**
Ni(40)Fe(60)-SDC	LSGM/SSC	500	254	[S1]
Ni-SDC	LSGM/SSC	500	118	[S1]
Ni(97.5)Mo(2.5)-SDC	LSGM/SSC	500	290	[S2]
LSTNC-SDC	SDC/BSCF	350	361	[S3]
LSTN-SDC	SDC/BSCF	350	161	[S3]
LSTC-SDC	SDC/BSCF	350	98	[S3]
r-PSCFRu	SDC/BCFZY	400	374	[S4]
r-PSCF	SDC/BCFZY	400	288	[S4]
LZN-YSZ	YSZ/MNMO-YSZ	/	100	[S5]
PZN-YSZ	YSZ/MNMO-YSZ	/	109	[S5]
NZN-YSZ	YSZ/MNMO-YSZ	/	114	[S5]
SZN-YSZ	YSZ/MNMO-YSZ	/	132	[S5]
GDZ-YSZ	YSZ/MNMO-YSZ	/	142	[S5]
Ni-YSZ	YSZ/Ag	400	75	[S6]

LSGM: $La_{0.9}Sr_{0.1}Ga_{0.8}Mg_{0.2}O_{2.85}$, SSC: $Sm_{0.5}Sr_{0.5}CoO_{3-\delta}$, LSTNC: $La_{0.52}Sr_{0.28}Ti_{0.94}Ni_{0.03}Co_{0.03}O_{3-\delta}$, LSTN: $La_{0.52}Sr_{0.28}Ti_{0.94}Ni_{0.06}O_{3-\delta}$, LSTC: $La_{0.52}Sr_{0.28}Ti_{0.94}Co_{0.06}O_{3-\delta}$, BSCF: $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$, PSCF: $Pr_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$, PSCFRu: $Pr_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.75}Ru_{0.05}O_{3-\delta}$, LZN: $La_2Zr_{1.95}Ni_{0.05}O_{7+\delta}$, PZN: $Pr_2Zr_{1.95}Ni_{0.05}O_{7+\delta}$, NZN: $Nd_2Zr_{1.95}Ni_{0.05}O_{7+\delta}$, SZN: $Sm_2Zr_{1.95}Ni_{0.05}O_{7+\delta}$, GDZ: $Gd_2Zr_{1.95}Ni_{0.05}O_{7+\delta}$, MNMO: $Mg_{0.4}Ni_{1.4}Mn_{1.2}O_4$

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