

Supplementary information

Highly efficient and stable perovskite cathode with *in-situ* exsolved NiFe alloy nanoparticles for CO₂ electrolysis

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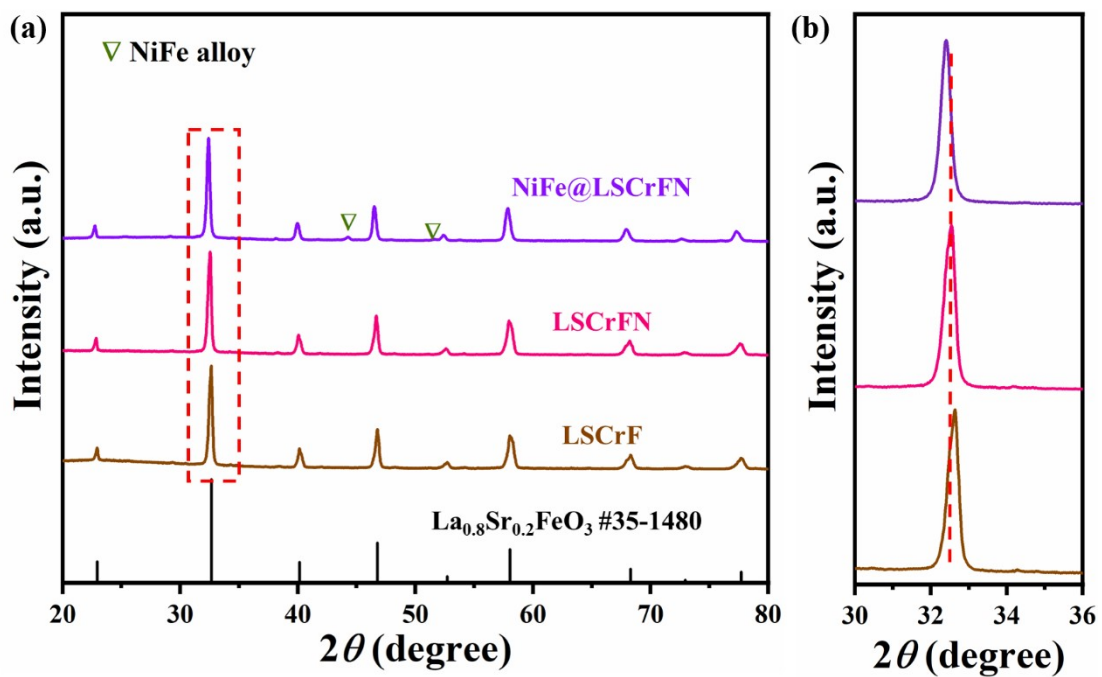


Fig. S1 (a) XRD patterns of LSCrF, LSCrFN and NiFe@LSCrFN. (b) Enlarged XRD patterns at 30-36° of (a).

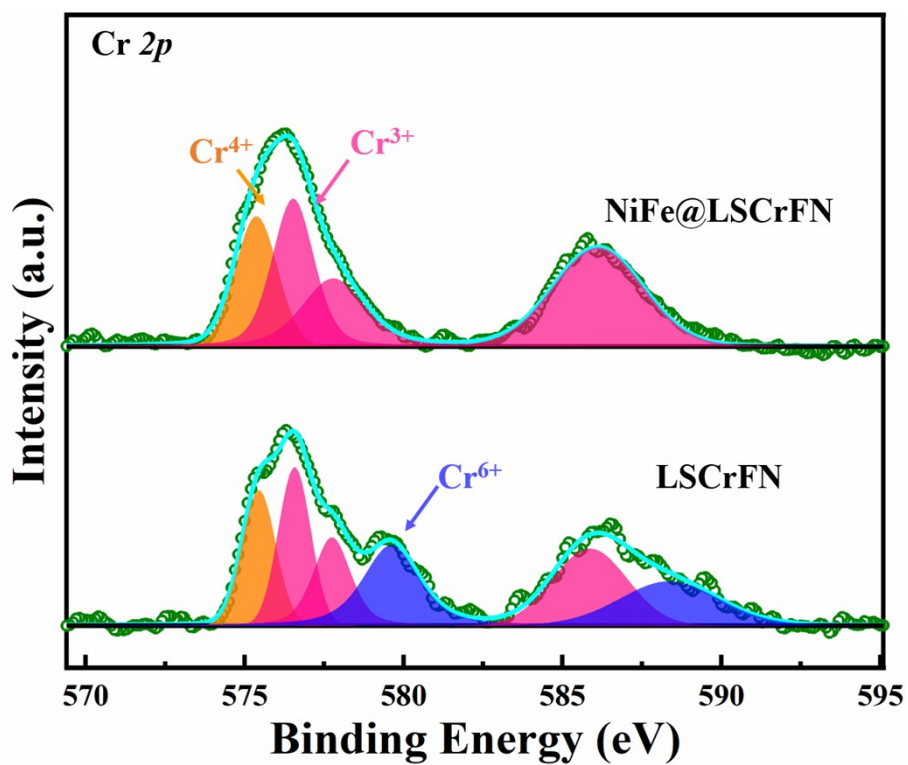


Fig. S2 XPS spectra of Cr 2p for LSCrFN and NiFe@LSCrFN.

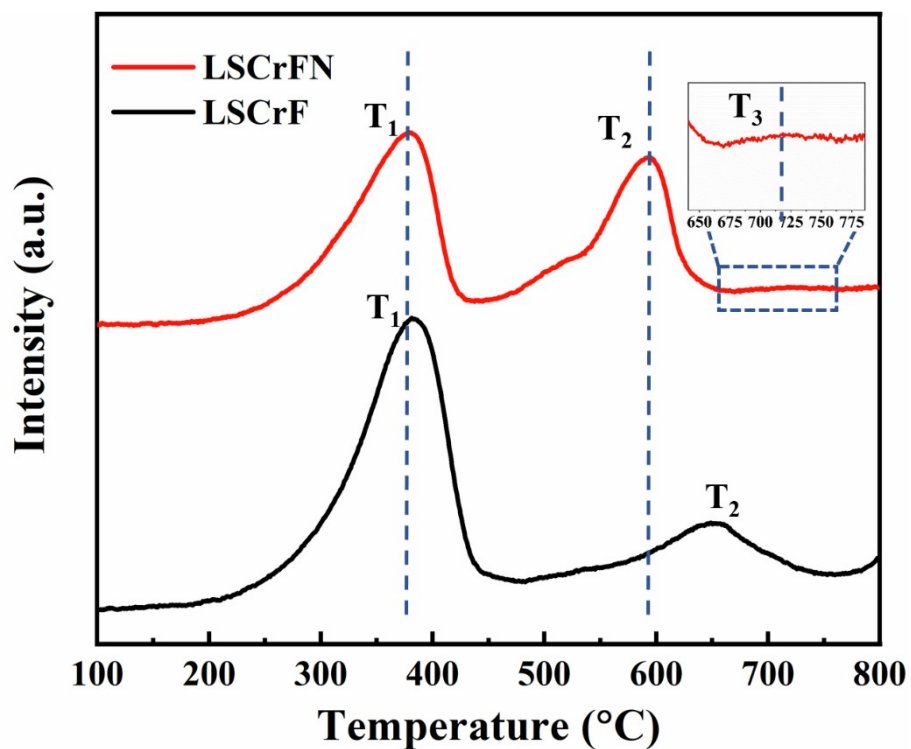


Fig. S3 TPR profiles in hydrogen for LSCrFN and LSCrF sample.

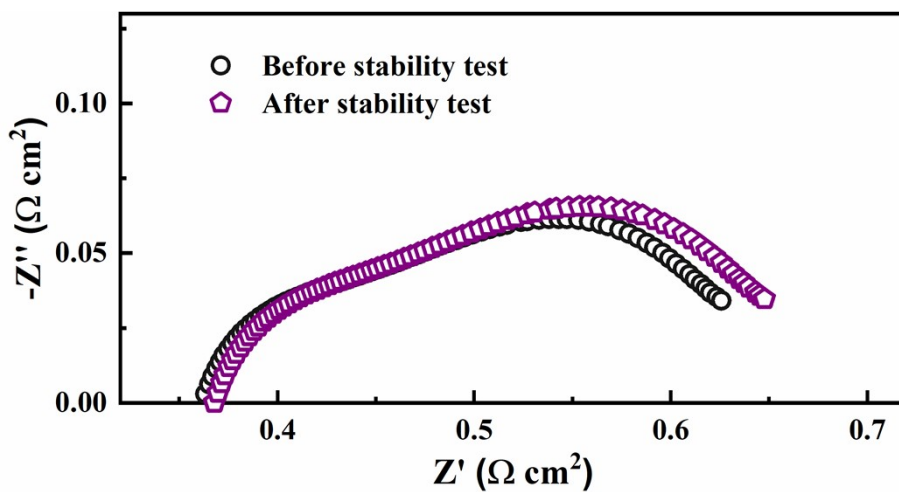


Fig. S4 The impedance spectra of Cell-2 before and after the stability test.

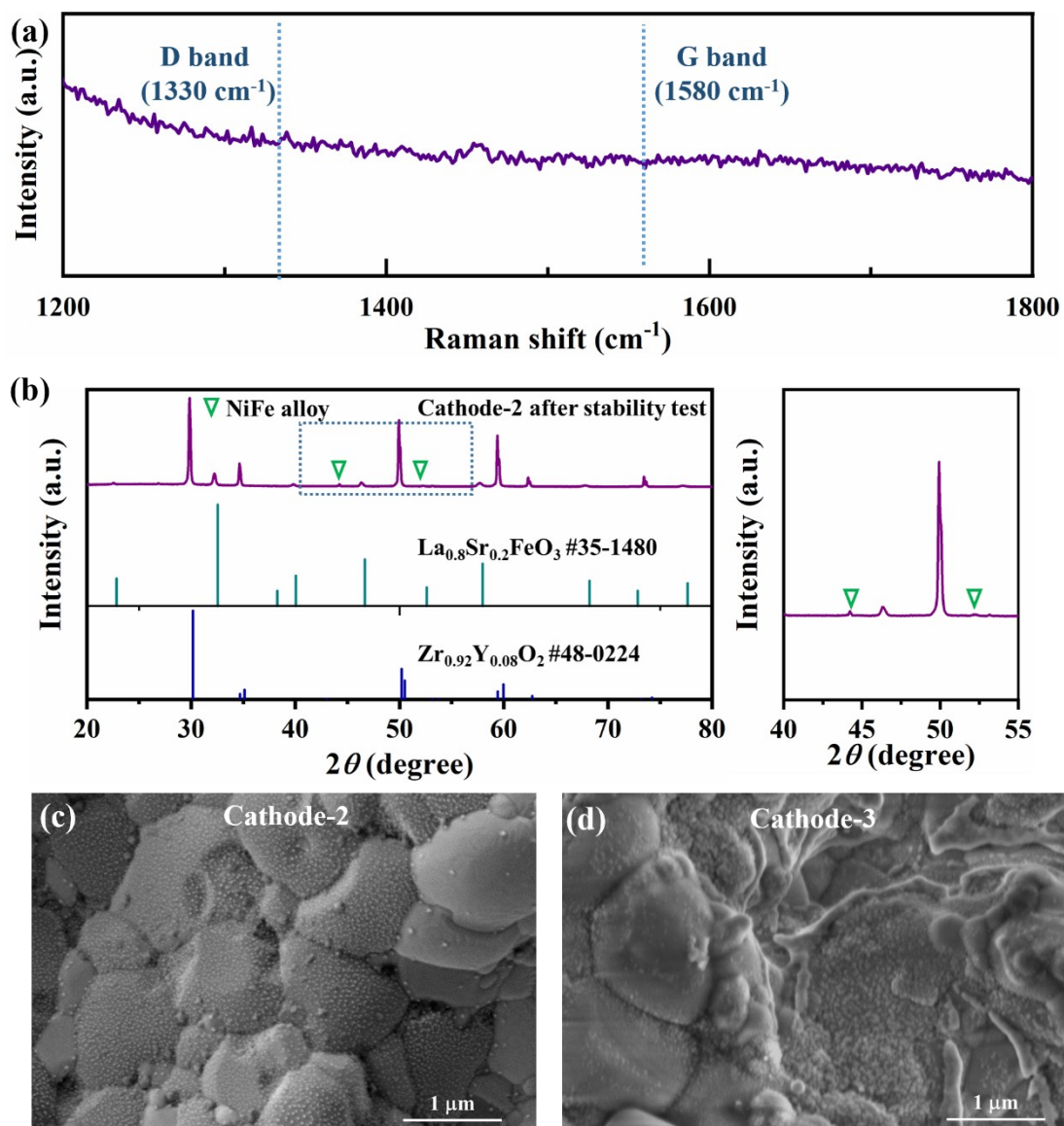


Fig. S5 (a) Raman spectra collected from the surface of Cathode-2 after stability test; (b) XRD patterns of Cathode-2 after test; Sectional SEM images of (c) Cathode-2 and (d) Cathode-3 after stability test.

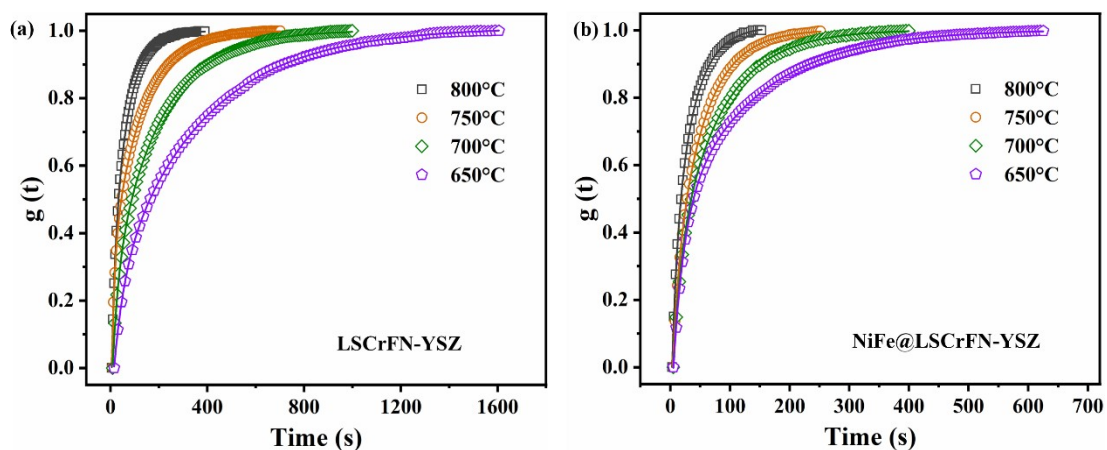


Fig. S6 Electrical conductivity relaxation curves of (a) LSCrFN-YSZ and (b) NiFe@LSCrFN-YSZ at 650-800°C

Table S1 XPS analysis of Ni 3*p* for the LSCrFN and NiFe@LSCrFN.

sample	Ni ⁰ (at%)	Ni ²⁺ (at%)
LSCrFN	0	100
NiFe@LSCrFN	33.3	72.2

Table S2 XPS analysis of Fe 2*p* for the LSCrFN and NiFe@LSCrFN.

sample	Fe ⁰ (at%)	Fe ³⁺ (at%)	Fe ²⁺ (at%)
LSCrFN	0	61.9	38.1
NiFe@LSCrFN	6.6	54.9	38.5

Table S3 XPS analysis of Cr 2*p* for the LSCrFN and NiFe@LSCrFN.

sample	Cr ⁶⁺ (at%)	Cr ⁴⁺ (at%)	Cr ³⁺ (at%)
LSCrFN	28.5%	16.7%	54.8%
NiFe@LSCrFN	0	24.3%	75.7%

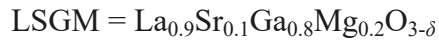
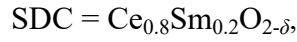
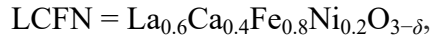
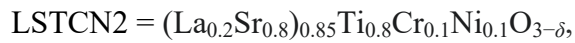
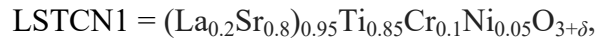
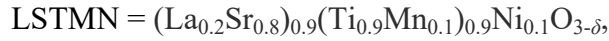
Table S4 XPS analysis of O 1*s* for the LSCrFN and NiFe@LSCrFN.

sample	O _L (at%)	O _V (at%)	O _C (at%)
LSCrFN	46.3	25.3	28.4
NiFe@LSCrFN	41.0	35.3	23.7

Table S5 Comparison of performance at 800°C and 1.5 V for direct CO₂ electrolysis of Cell-2 with other SOECs.

Fuel electrode	Exsolved nanoparticles	Electrolyte Thickness (μm)	Current density (A·cm ⁻²)	Polarization resistance (Ω·cm ²)	Refs
LSCMC-SDC	Cu	YSZ (50)	0.25	0.50 at 2 V	[1]
LSTMN-YSZ	Ni	YSZ (46)	0.075	2.20 at 1.6V	[2]
LSTCN1-SDC	Ni	YSZ (28)	0.4	0.51 at 1.6 V	[3]
LSTCN2-SDC	Ni	LSGM (55.5)	0.6	0.43 at 1.6 V	[4]
LCFN-GDC	NiFe	YSZ (300)	0.9	0.40 at 1.3V	[5]
LSCrFN-YSZ	NiFe	YSZ (13)	1.15	0.27@1.5V	This work

Notes: LSCMC = (La_{0.75}Sr_{0.25})_{0.9}(Cr_{0.5}Mn_{0.5})_{0.9}Cu_{0.1}O_{3-δ},



References

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