In-situ Construction of Hetero-structured Perovskite Composites with Exsolved Fe and Cu Metallic Nanoparticles as Efficient CO_2 Reduction Electrocatalyst for High Performance Solid Oxide Electrolysis Cells

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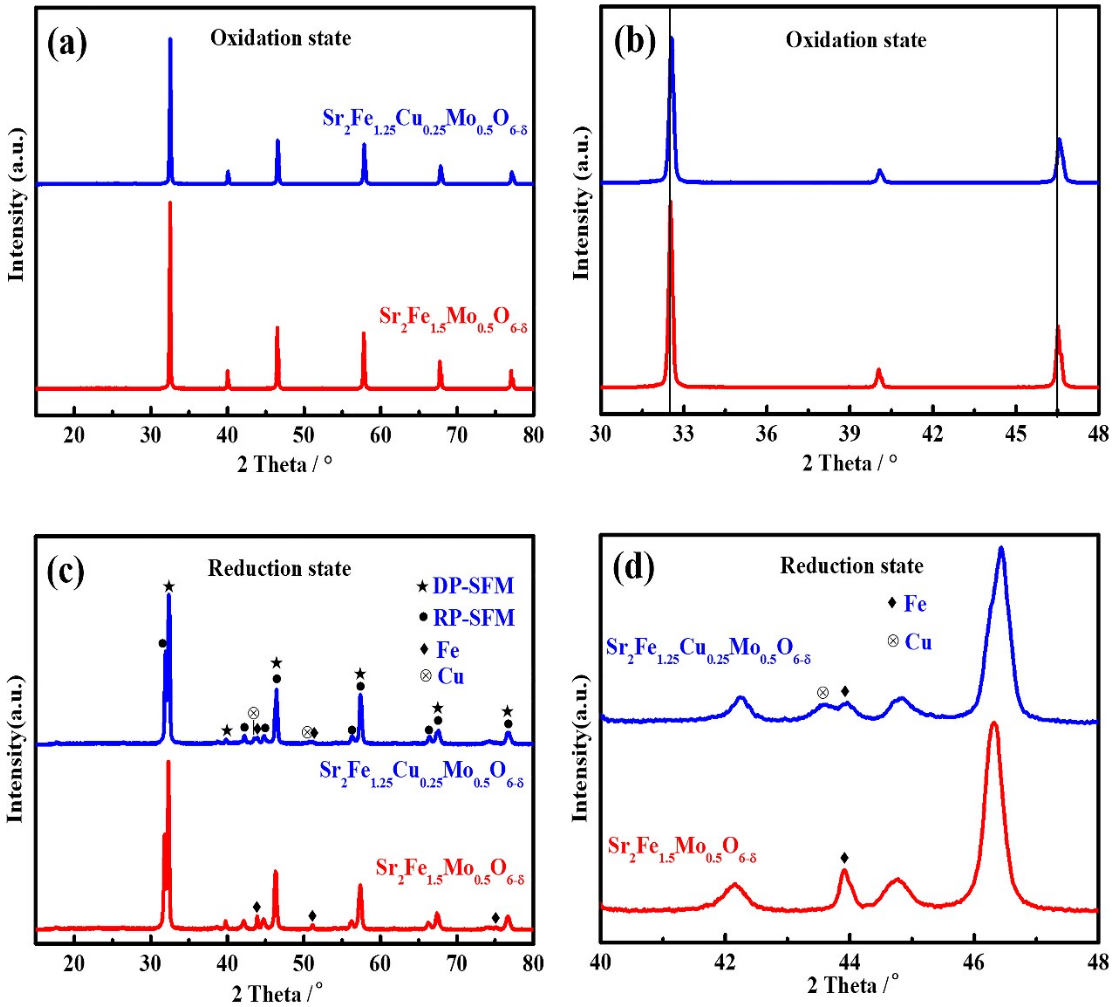

Fig. S1. (a) As-synthesized $Sr_2Fe_{1.5}Mo_{0.5}O_{6-\sigma}$ (SFM) and $Sr_2Fe_{1.25}Cu_{0.25}Mo_{0.5}O_{6-\sigma}$ (SFCuM) powders; (b) magnification of (a); (c) reduced $Sr_2Fe_{1.5}Mo_{0.5}O_{6-\sigma}$ (SFM) and $Sr_2Fe_{1.25}Cu_{0.25}Mo_{0.5}O_{6-\sigma}$ (SFCuM) powders; (d) magnification of (c).

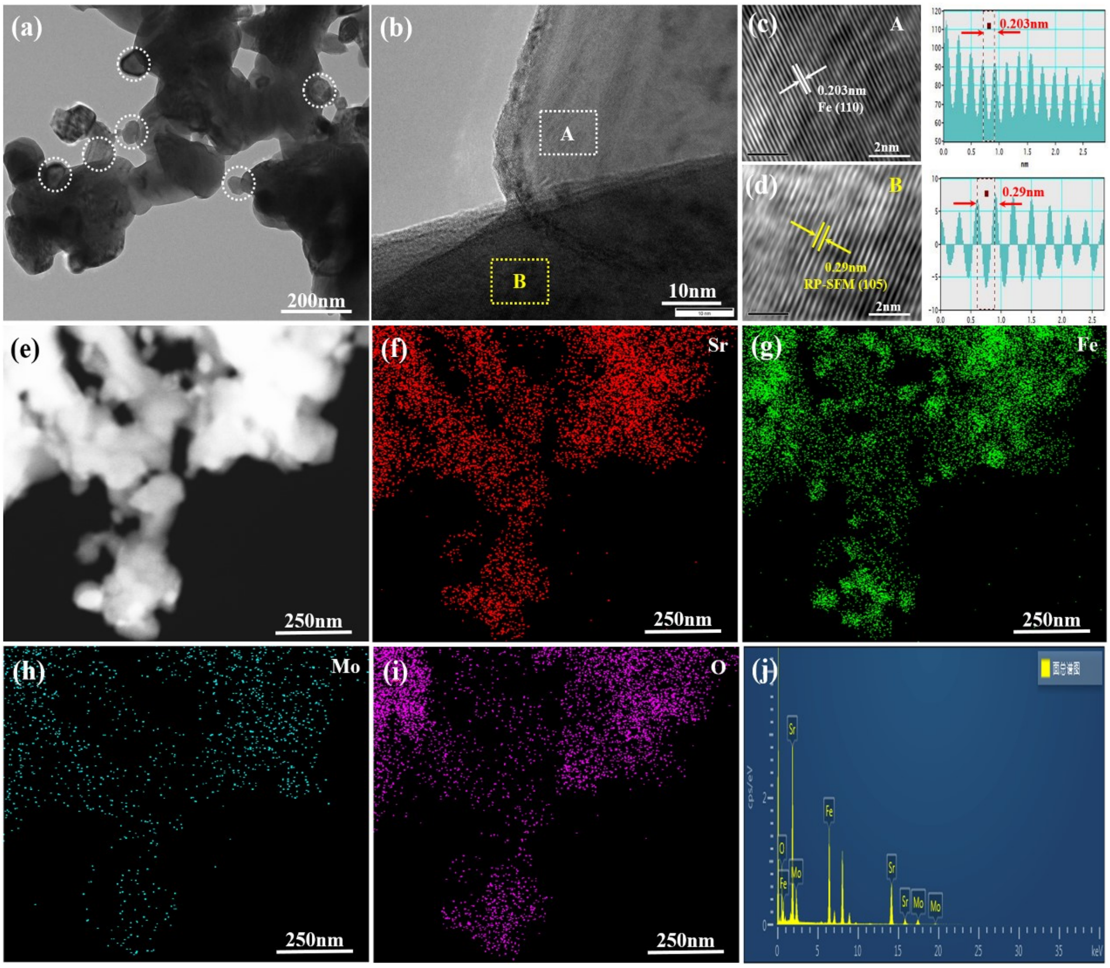

Fig. S2. (a-d) HR-TEM micrographs of the reduced $Sr_2Fe_{1.5}Mo_{0.5}O_{6-\sigma}$ (SFM) particles; (e–i) TEM-EDS elemental mappings of the reduced SFM particles, (j) amount of each element in SFM.

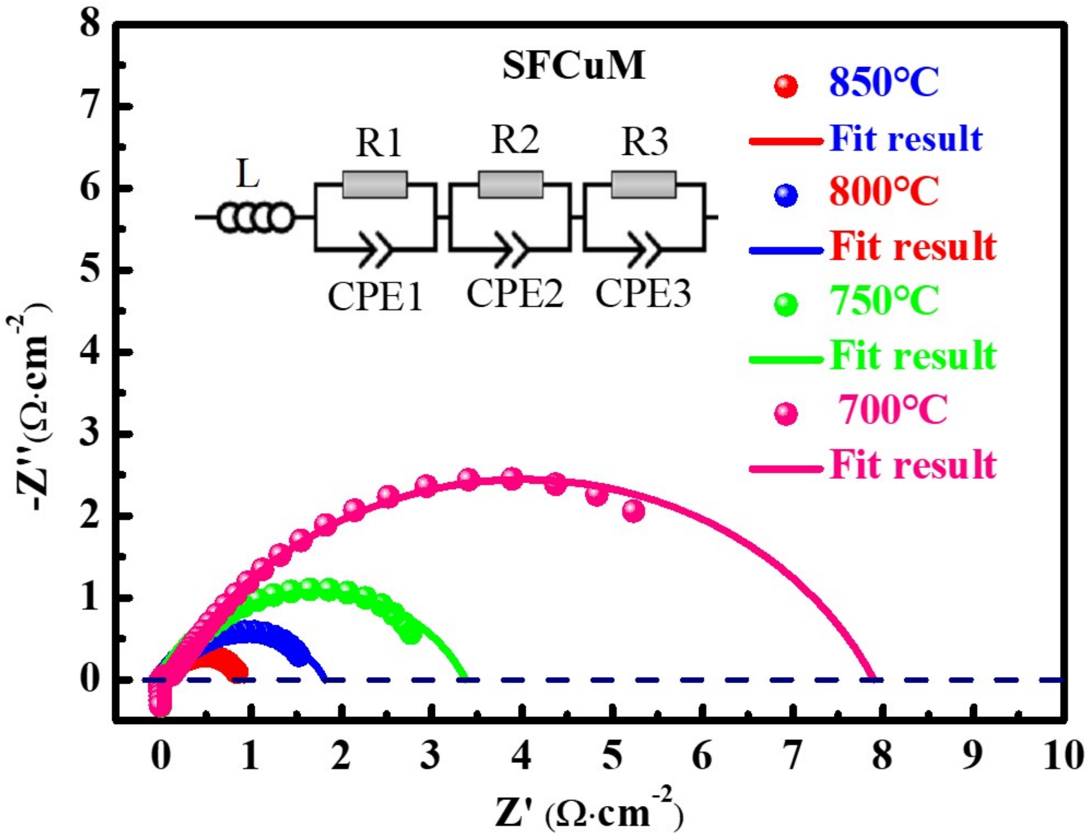

Fig. S3. EIS of LSGM electrolyte-supported symmetrical cells with the configuration SFCuM/LDC/LSGM/LDC/SFCuM under a 1:1 CO–CO_2 atmosphere at different operating temperatures.

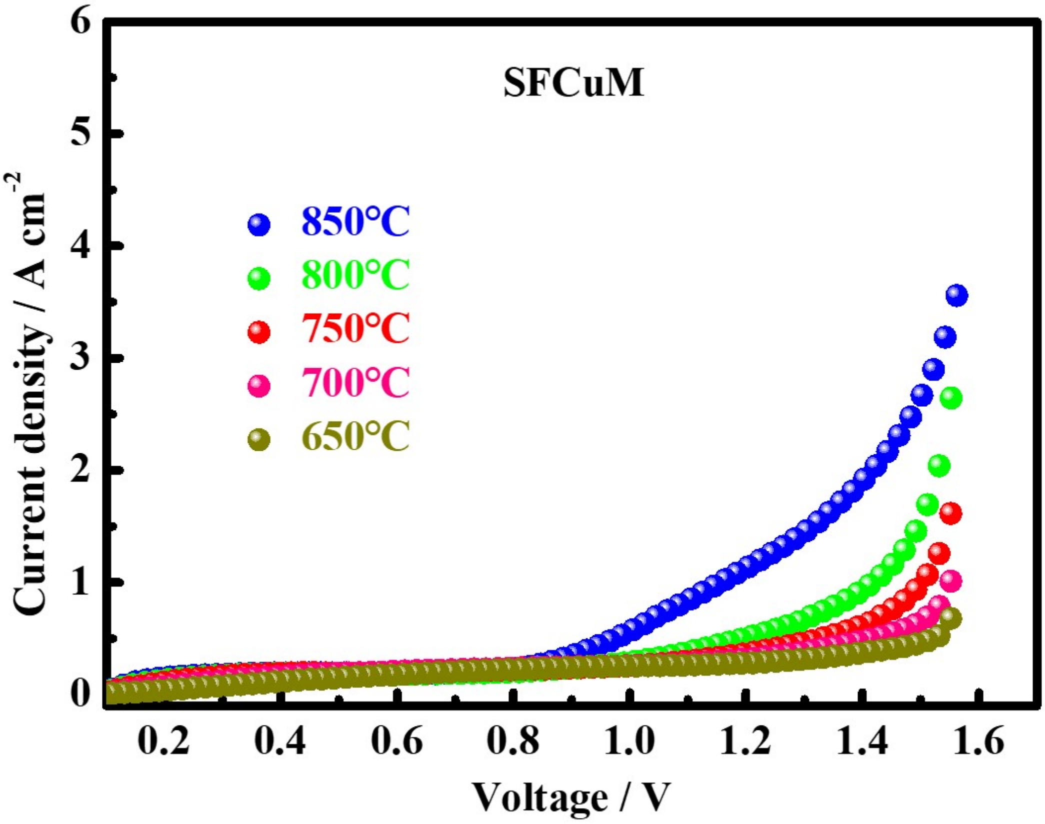

Figure S4. Current density of LSGM electrolyte-supported single cells with the configuration SFCuM/LDC/LSGM/LSCF-SDC under pure CO_2 atmosphere at different operating temperatures.

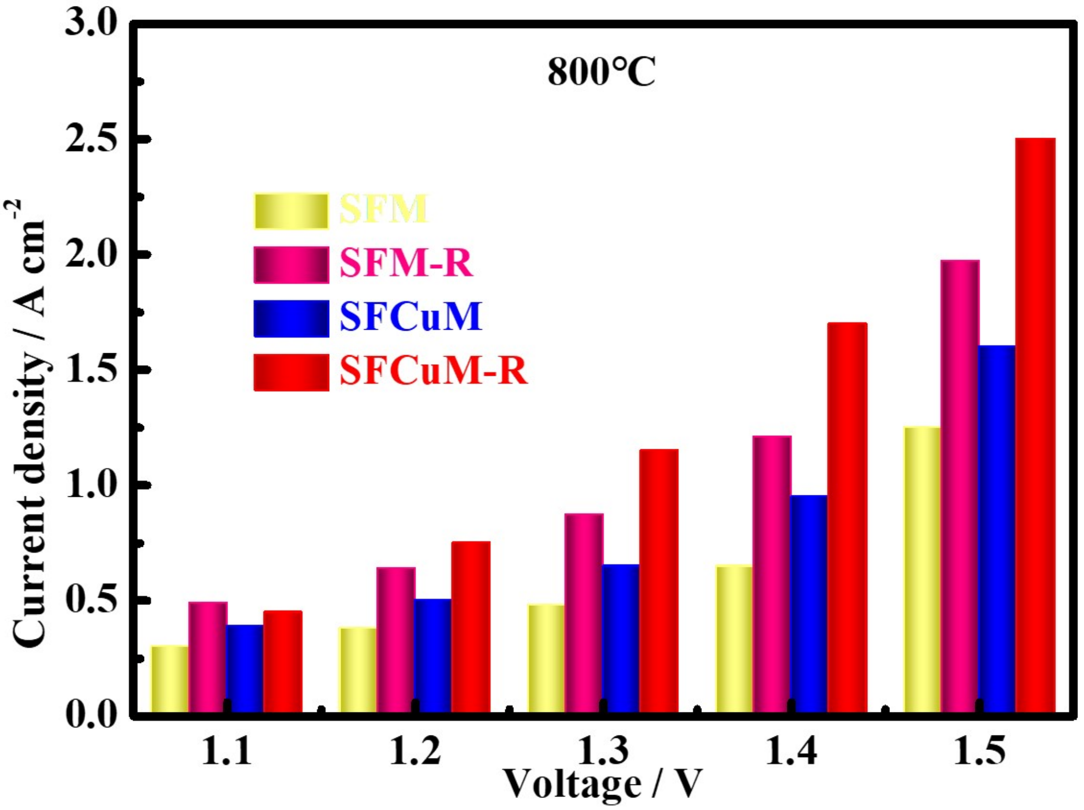

Figure S5. Current density comparison of the LSGM-electrolyte supported single cell with various cathodes at the operating temperature of 800°C.

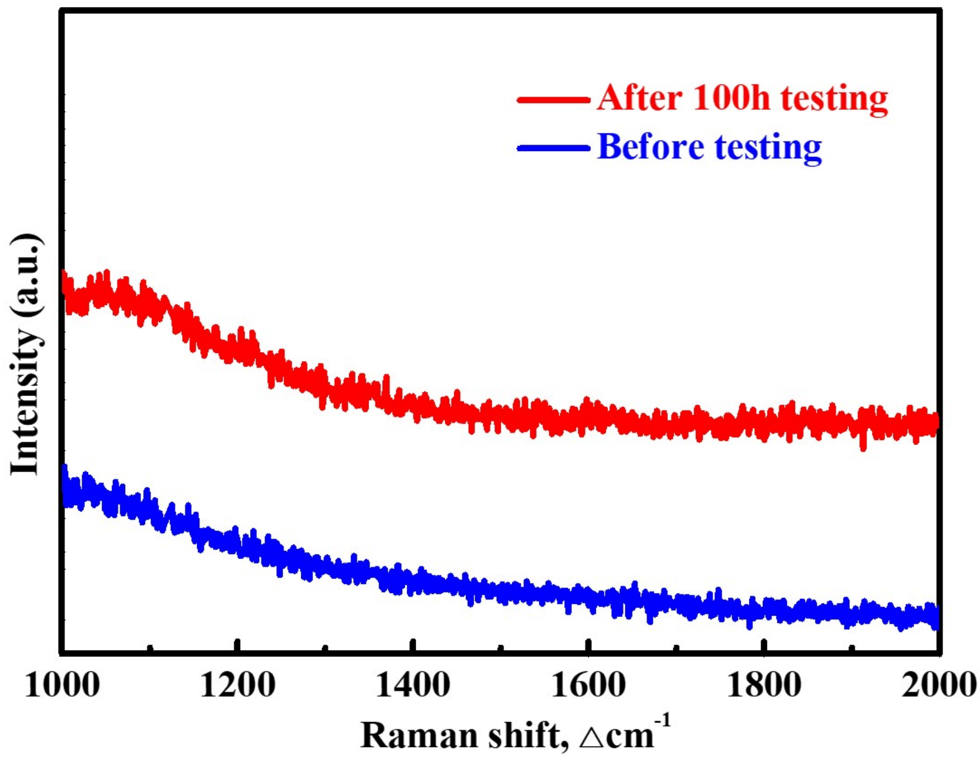

Figure S6. Raman spectroscopy of the SFCuM-R cathode before and after long-term stability testing.

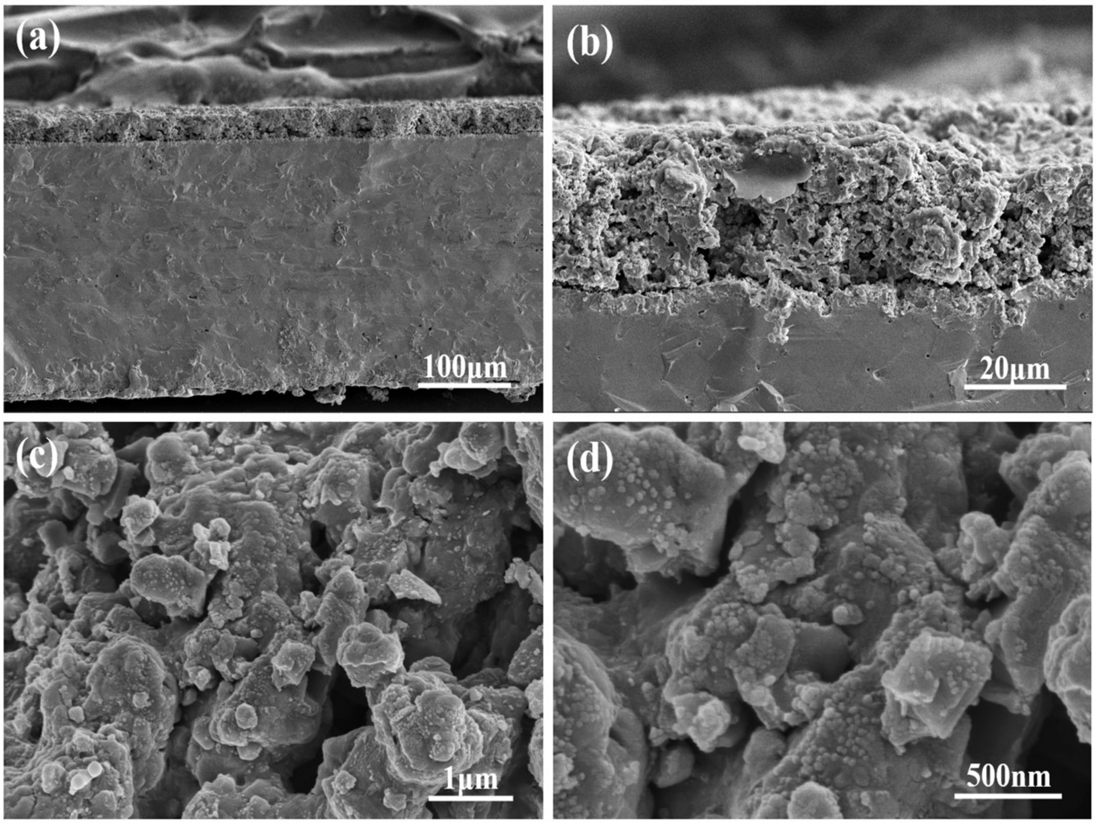

Figure S7. Cross section images of LSGM electrolyte supported single cell with SFCuM-R as the cathode and LSCF-SDC as the anode after 100h long-term stability testing.

Table S1 Superficial C and O stoichiometry of the $Sr_2Fe_{1.25}Cu_{0.25}Mo_{0.5}O_{6-\delta}$ electrode based on XPS peak fitting results.

Superficial elements / Atomic %	CO_3^{2-}/C-C	O_{ad}/CO_3^{2-}	O_{ad}/O_{latt}
Oxidizing	0.56	3.63	2.40
Reducing	0.58	3.75	4.54

Table S2 Superficial elements stoichiometry of the $Sr_2Fe_{1.25}Cu_{0.25}Mo_{0.5}O_{6-\delta}$ electrode based on XPS results

Superficial elements /Atomic %	Sr	Fe	Mo	Cu	O	C	Sr/(Fe+Mo+Cu)	CO_3^{2-}/Sr
Oxidizing	11.54	2.25	2.81	2.44	47.99	32.97	1.54	0.76
Reducing	11.08	1.88	1.82	2.03	47.31	35.87	1.93	0.84

Table S3. Current density comparison for CO_2 electrolysis obtained at 1.5 V and 800 °C with diverse cathodes.

Fuel electrodes	Electrolyte	Anode	Feeding gas	Current density	Refs.
$La_{0.6}Sr_{0.4}Fe_{0.8}Ni_{0.2}O_{3-\delta}$	YSZ	LSCF-SDC	CO_2–30% CO	0.75	1
Ce-$La_{0.7}Sr_{0.3}Cr_{0.5}Fe_{0.5}O_{3-\delta}$	YSZ	LSCF	CO_2–30% CO	0.9	2
$Sr_2Fe_{1.5}Mo_{0.5}O_{6-\delta}F_{0.1}$	LSGM	LSGM-SDC	100% CO_2	1.36	3
NiFe@$La_{0.6}Sr_{0.4}Fe_{0.8}Mn_{0.2}O_3$	LSGM	BLC	CO_2–1% CO	1.70	4
CoFe@$(Pr_{0.4}Sr_{0.6})_3(Fe_{0.85}Mo_{0.15})_2O_7$	YSZ	LSCF-SDC	CO_2–30% CO	1.01	5
$Sr_2Fe_{1.4}Mn_{0.1}Mo_{0.5}O_{6-\delta}$-SDC	LSGM	LSCF-SDC	100% CO_2	1.35	6
Co@$La_{1.2}Sr_{0.8}Co_{0.4}Mn_{0.6}O_4$-GDC	LSGM	LSCF-GDC	CO_2–30% CO	0.75	7
$FeNi_3$@$Sr_2Fe_{1.5}Mo_{0.5}O_{6-\delta}$	LSGM	LSM-GDC	CO_2–5% N_2	0.90	8
$Sr_2Fe_{1.25}Cu_{0.25}Mo_{0.5}O_{6-\delta}$	LSGM	LSCF-SDC	100% CO_2	1.60	This work
$Sr_2Fe_{1.25}Cu_{0.25}Mo_{0.5}O_{6-\delta}$-R	LSGM	LSCF-SDC	100% CO_2	2.5	This work

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