Supporting Information

Understanding CeO_2 Modified Defective Carbon as Electrocatalyst for Electrochemical Reduction of CO_2

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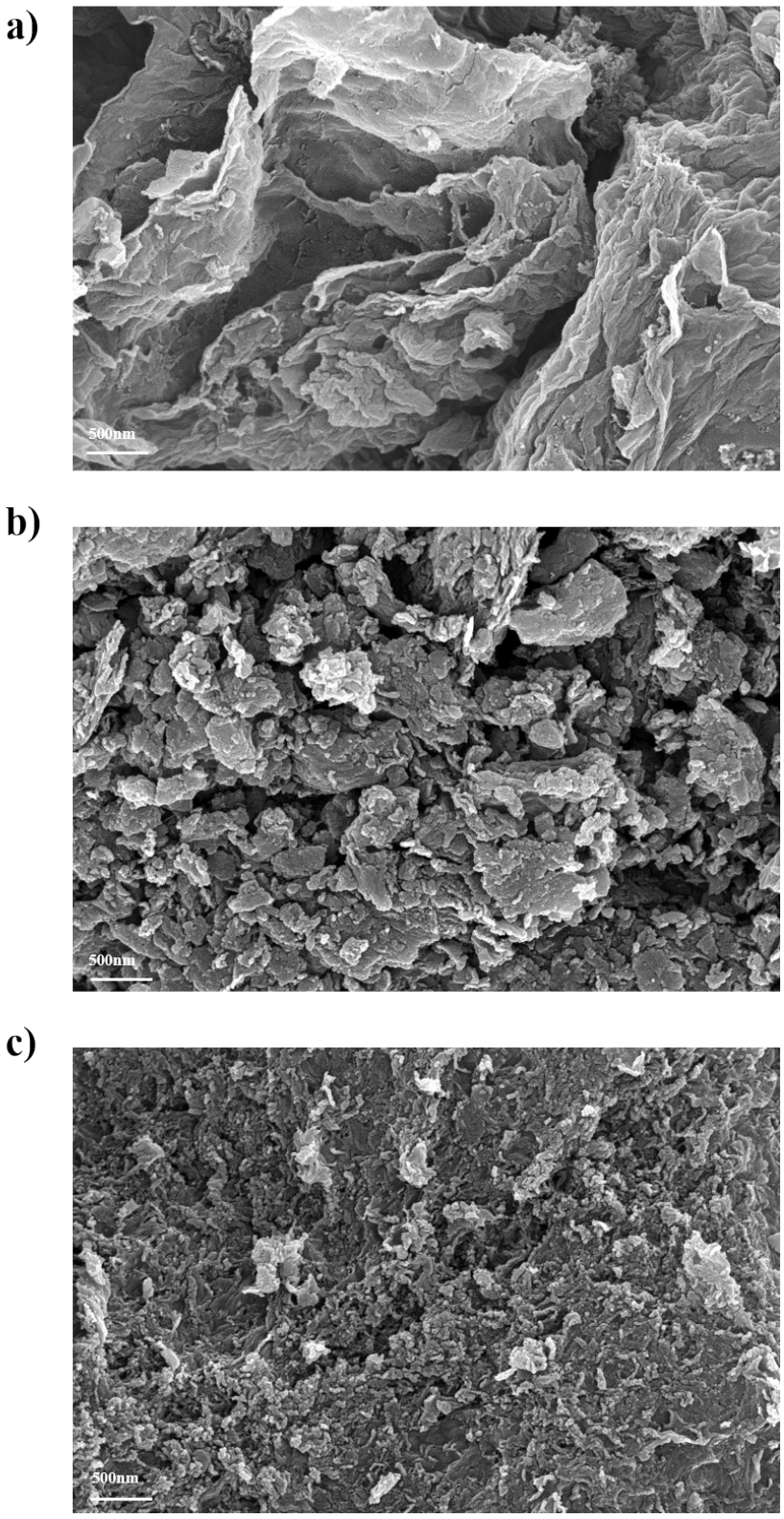

Figure S1. a) SEM image of V_0-C-1300, b) SEM image of V_0-CeO_2/C-900, c) SEM image of V_0-CeO_2/C-1100.

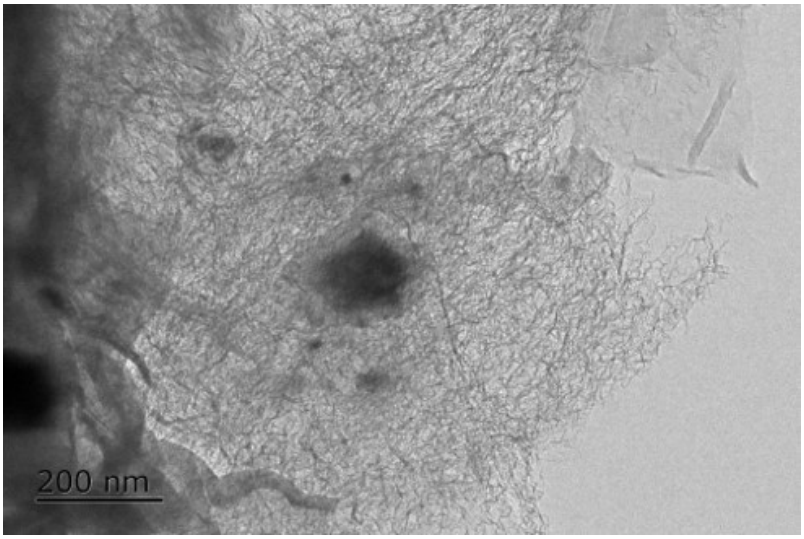

Figure S2. a) TEM image of V_0-CeO_2/C-1300.

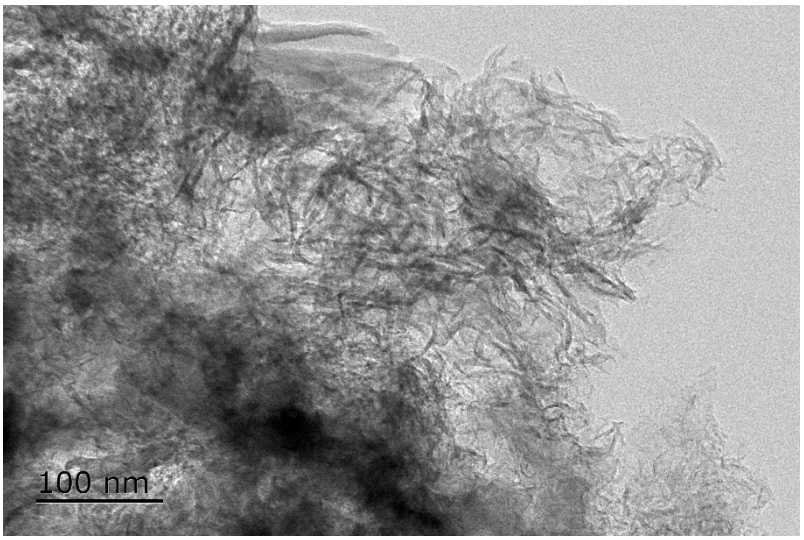

Figure S3. a) TEM image of V_0-CeO_2/C-900.

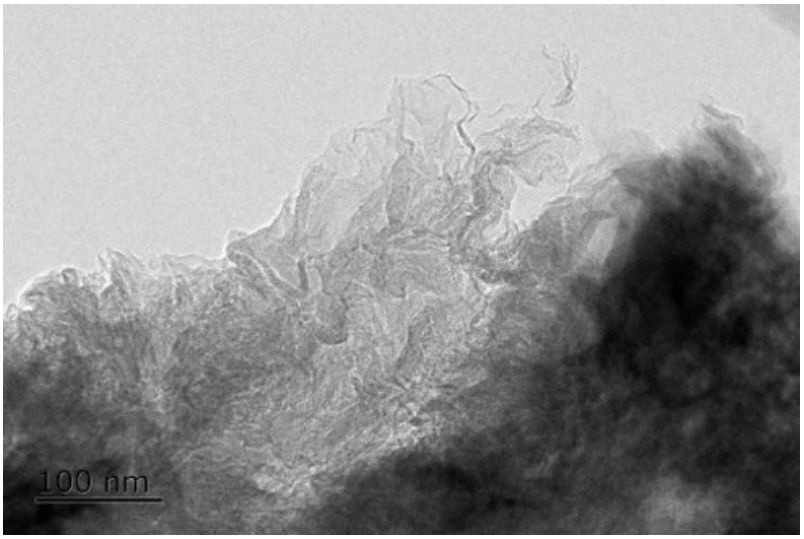

Figure S4. a) TEM image of V_0-C-1300.

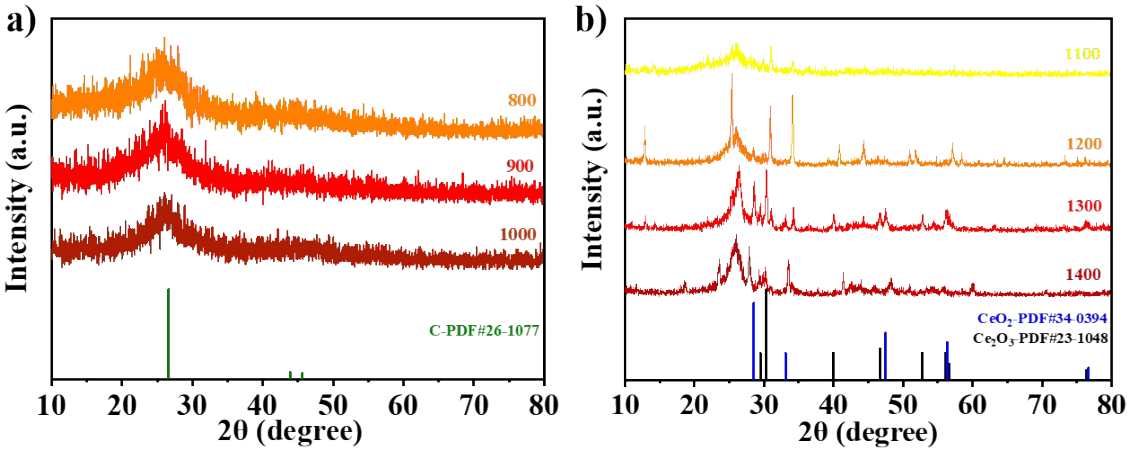

Figure S5. a-b) XRD of V_0-CeO_2/C at different temperatures.

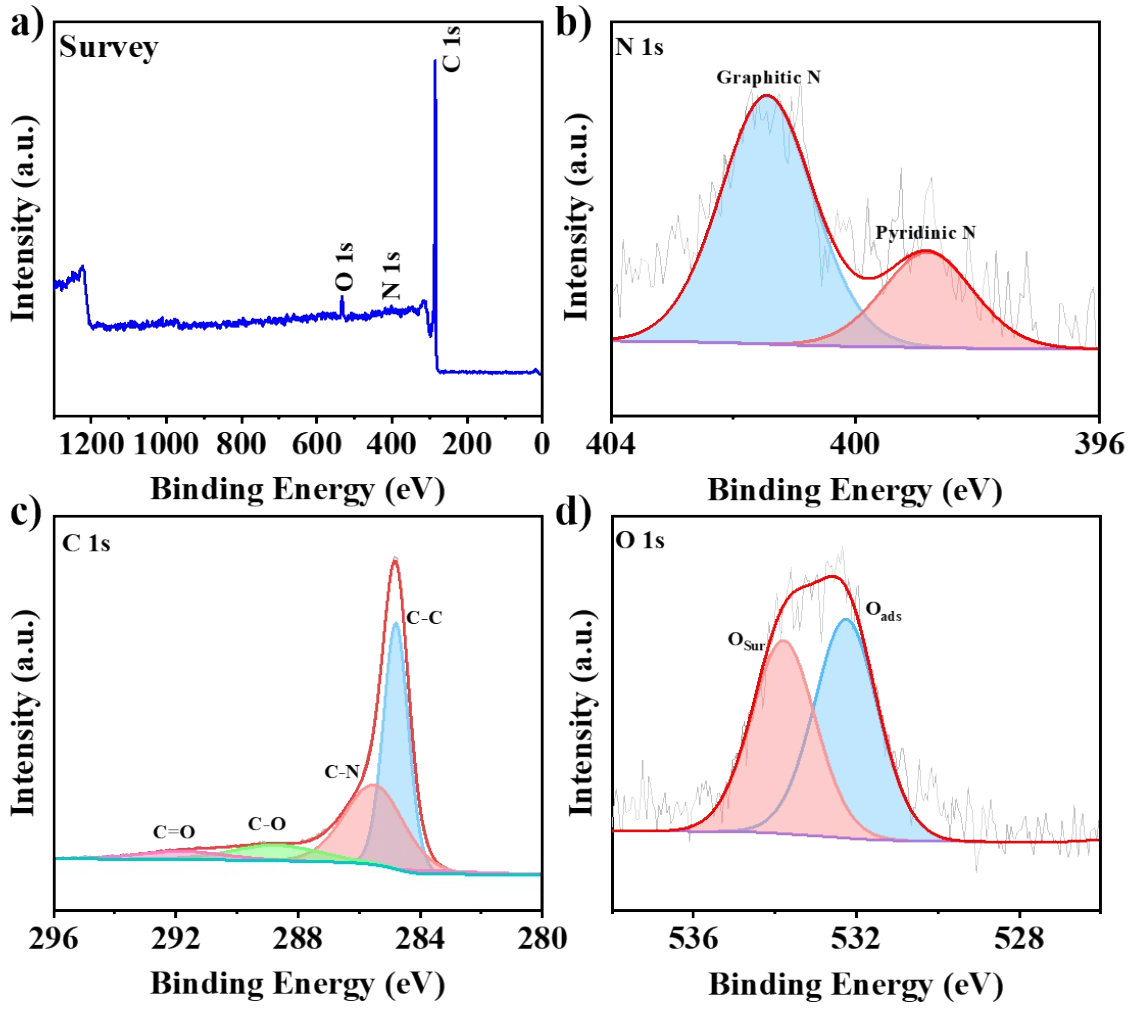

Figure S6. XPS spectra of V_0-C-1300: (a) survey spectra, (b) N1s, (c) C1s, (d) O1s.

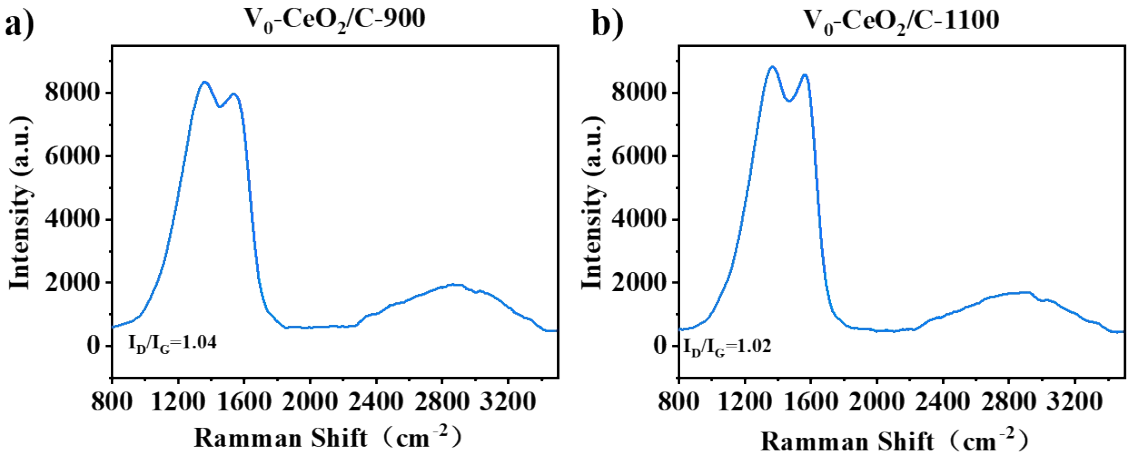

Figure S7. Raman spectrum of: a) V_0-CeO_2/C-900, b) V_0-CeO_2/C-1100.

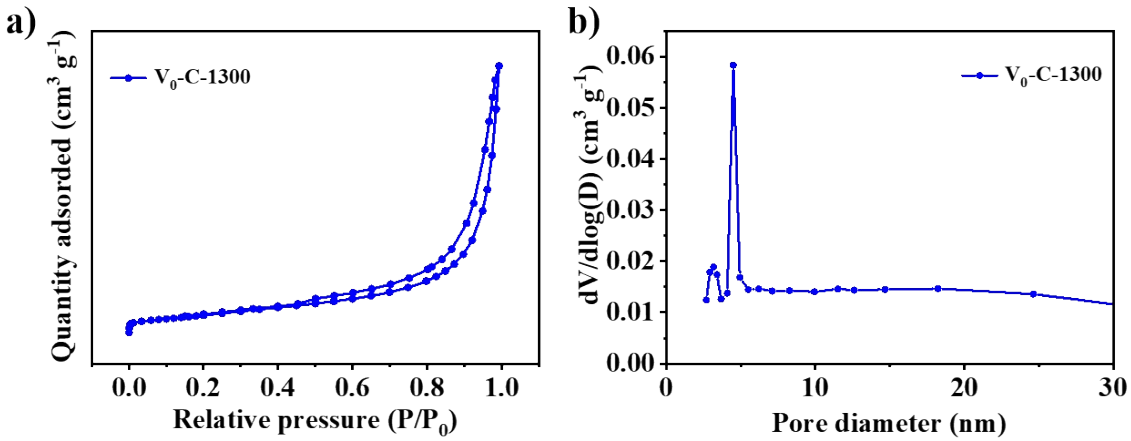

Figure S8. a) N_2 adsorption/desorption isotherms, and b) pore size distribution of V_0-C-1300.

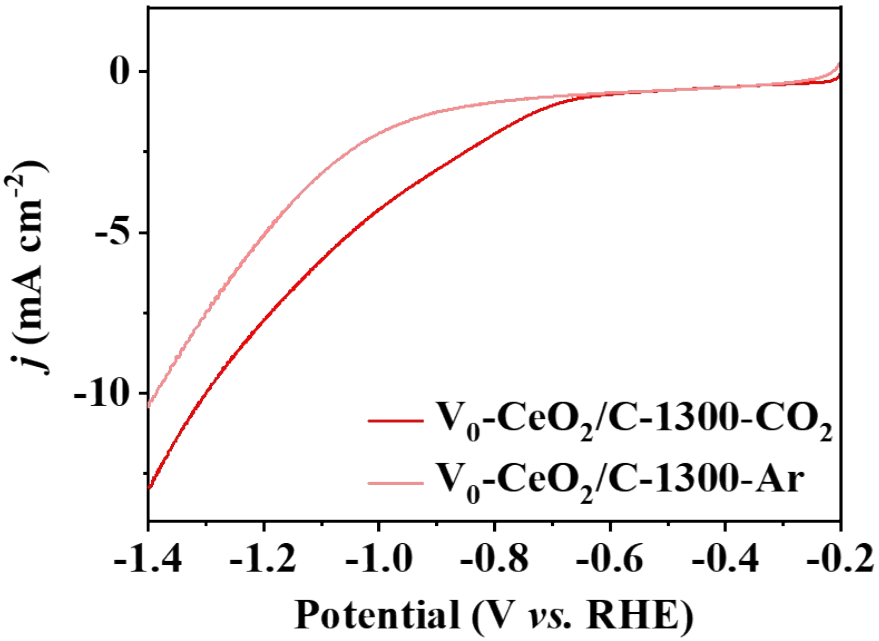

Figure S9. LSV curves of V_0-CeO_2/C-1300 in different atmospheres.

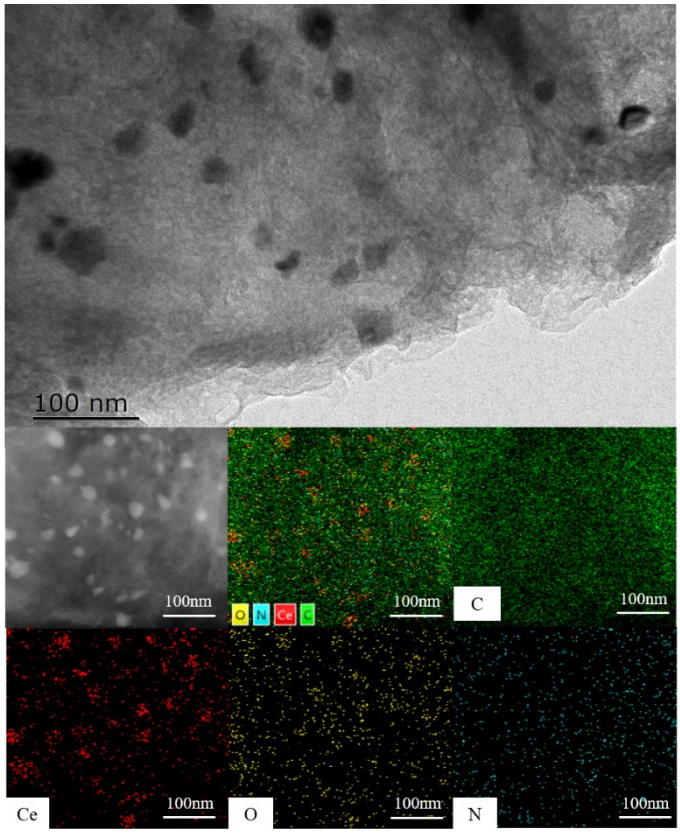

Figure S10. TEM image and EDS elemental mappings of V_0-CeO_2/C-1300 after stability test.

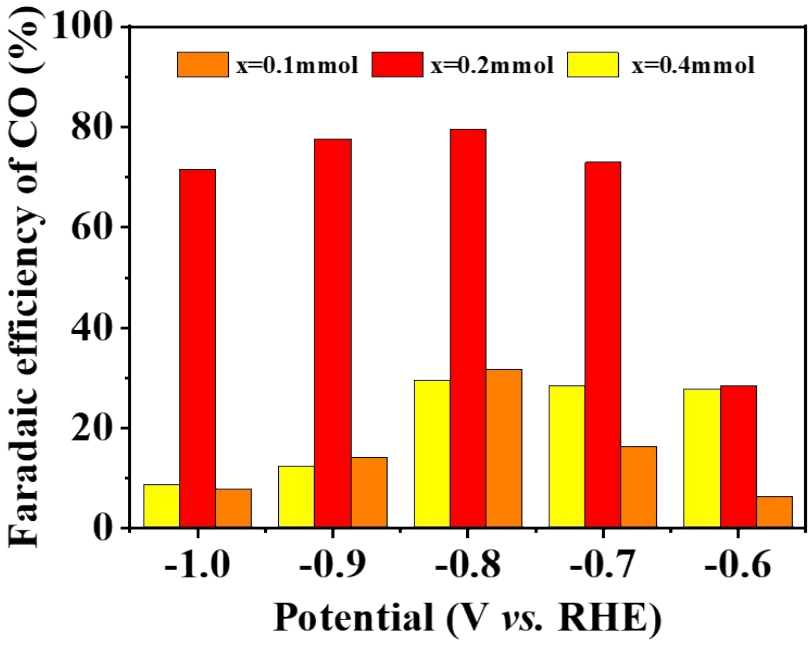

Figure S11. FE_{CO} of V_0-CeO_2/C-1300.

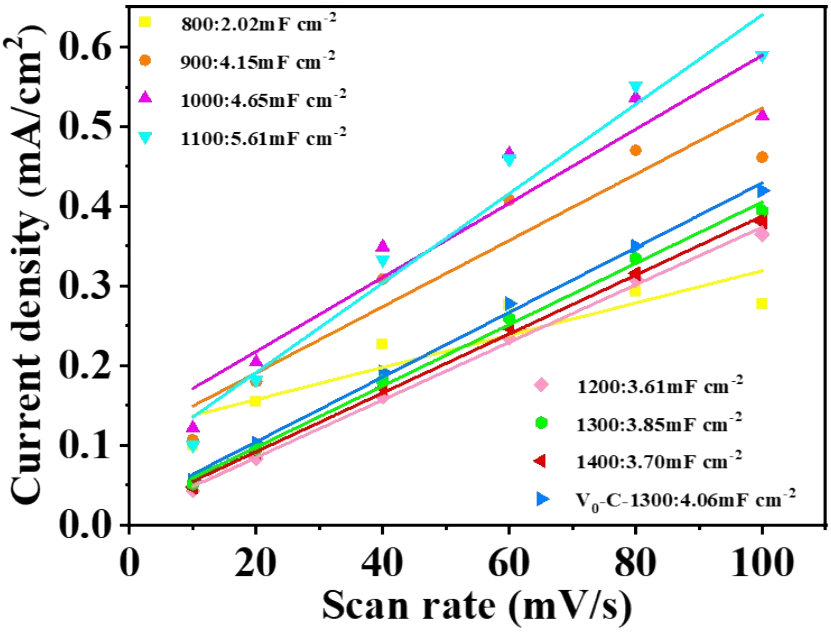

Figure S12. The electrochemical active area of V_0-CeO_2/C at different temperatures and V_0-C-1300.

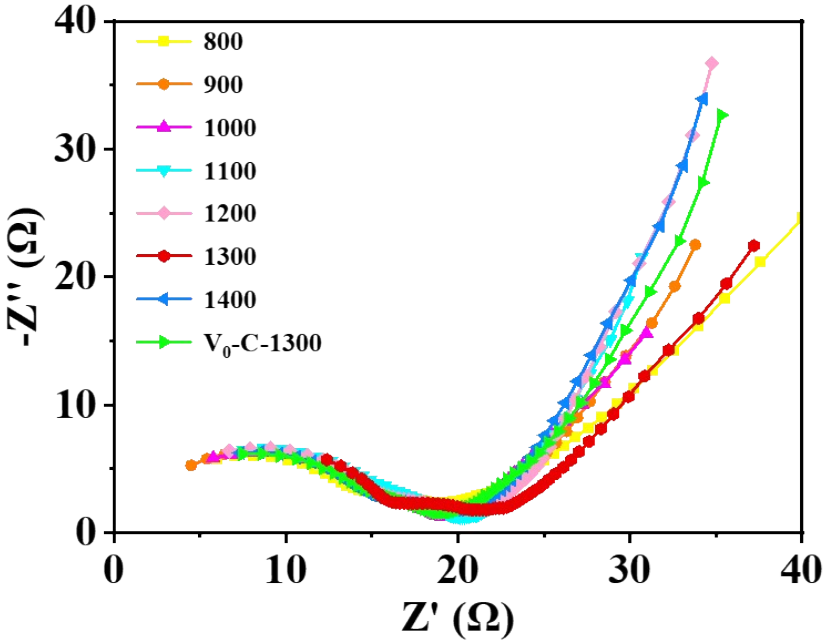

Figure S13 The electrochemical impedance spectroscopic (EIS) Nyquist plots of V_0-CeO_2/C at different temperatures and V_0-C-1300.

Table S1. The EDS element content of V_0-C-1300.

Element	Line Type	k factor	Absorption Correction	Wt%	Wt% Sigma
C	K series	2.50675	1.00	95.14	0.45
N	K series	3.14061	1.00	0.48	0.34
Ce	L series	2.01965	1.00	4.39	0.30
Total:				100.00	

Table S2. EXAFS fitting parameters at the Ce L-edge for various samples (S_0^2=0.75 from CeO_2)

	shell	CN[a]	R[b](Å)	σ^{2c}(Å^2)	ΔE_0[d](eV)	R factor
CeO_2	Ce-O	8	2.32±0.01	0.0083	6.4±1.1	0.0179
$CeCl_3$	Ce-Cl	6.9±0.7	2.68±0.01	0.0107	-5.2±0.9	0.0175
	Ce-Cl	6.7±0.7	2.87±0.01	0.0107		
Ce-Sample	Ce-O	6.0±0.7	2.28±0.03	0.0202	3.3±2.1	0.0175

[a]*CN*: coordination numbers; [b]*R*: bond distance; [c]σ^2: Debye-Waller factors; [d] ΔE_0: the inner potential correction. R factor: goodness of fit. Error bounds that characterize the structural parameters obtained by EXAFS spectroscopy were estimated as CN±20%; R ± 1%; σ^2 ± 20%.

Table S3. The catalyst contains rare earth elements and the main product of CO_2RR is CO.

Chemical formula	j/mA cm^{-2}	Product composition	Main products (FE)	Electrolyte	Electrolyzer type	Ref.
This work	12.6	CO H_2	CO (79 %)	0.5M $KHCO_3$	H-type cell	
Eu–N–C	16	CO H_2	CO (59 %)	0.5M $KHCO_3$	H-type cell	[1]
Pr-NC-8	~0.25	CO H_2	CO (93 %)	0.5M $KHCO_3$	standard three electrode system	[2]
$La_{0.6}Sr_{0.4}Fe_{0.8}Ni_{0.2}O_{3-\delta}$	193	CO H_2	CO (99 %)	/	symmetrical half-cell	[3]
ZnLa/CN	2.5	CO H_2	CO (26 %)	0.1M $KHCO_3$	standard three electrode system	[4]
Y/NC and Sc/NC	~2	CO H_2	CO(88 %)/ CO(81%)	0.5M $KHCO_3$	H-type cell	[5]
$Ce_{0.016}Zn_{0.984}O$	24	CO H_2	CO (88 %)	0.5M $KHCO_3$	H-type cell	[6]

Reference

[1] X. Zeng, L. Liao, M. Wang, H. Wang, Rare-earth metal-N_6 centers in porous carbon for electrocatalytic CO_2 reduction, Physical Chemistry Chemical Physics 25 (2023) 20381-20394.

[2] F. Hu, L. Liao, B. Chi, H. Wang, Rare earth praseodymium-based single atom catalyst for high performance CO_2 reduction reaction, Chemical Engineering Journal 436 (2022)135271..

[3] C. Yang, Y. Tian, J. Pu, B. Chi, Anion Fluorine-Doped $La_{0.6}Sr_{0.4}Fe_{0.8}Ni_{0.2}O_{3-\delta}$ Perovskite Cathodes with Enhanced Electrocatalytic Activity for Solid Oxide Electrolysis Cell Direct CO_2 Electrolysis, ACS Sustainable Chemistry & Engineering 10 (2022) 1047-1058.

[4] Z Liang, L Song, M Sun, B Huang, Y Du, Tunable CO/H_2 ratios of electrochemical reduction of CO_2 through the Zn-Ln dual atomic catalysts[J]. Science advances, 2021, 7(47): eabl4915.

[5] J Liu, X Kong, L Zheng, X Guo, X Liu, J Shui, Rare earth single-atom catalysts for nitrogen and carbon dioxide reduction[J]. ACS nano, 2020, 14(1): 1093-1101.

[6] X Ren, Y Gao, L Zheng, Z Wang, P Wang, Z Zheng, Y Liu, H Cheng, Y Dai, B Huang, Oxygen vacancy enhancing CO_2 electrochemical reduction to CO on Ce-doped ZnO catalysts[J]. Surfaces and Interfaces, 2021, 23: 100923.