

Reconstruction-Driven YO_6 -Sn Interactions in Y-Doped SrSnO_3 for Stable Acidic CO_2 -to- HCOOH Electrocatalysis at Industrial Current Densities

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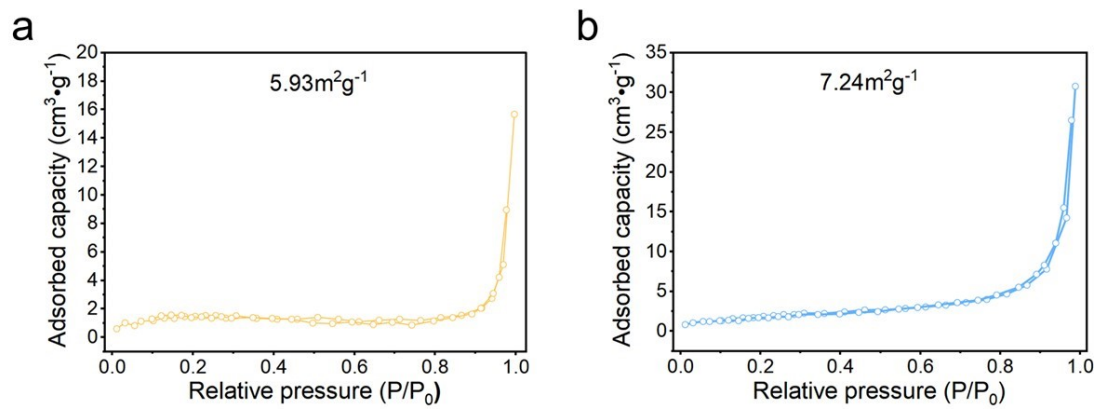


Fig. S1 N₂ adsorption-desorption isotherms and BET specific surface areas of SrSnO₃ and SrSn_{0.7}Y_{0.3}O₃.

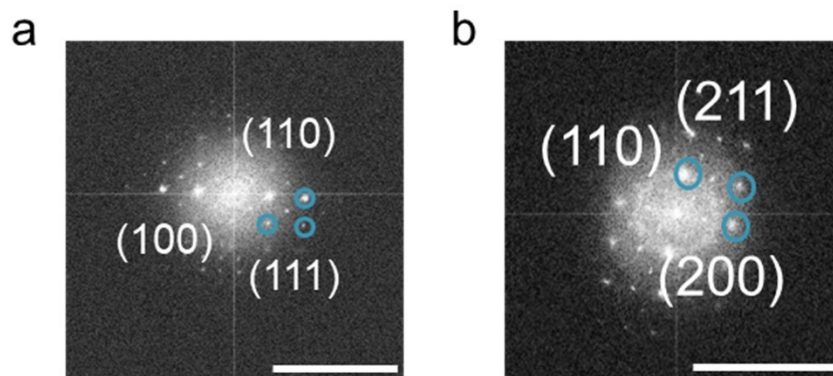


Fig. S2 The FFT patterns of the SrSnO_3 and $\text{SrSn}_{0.7}\text{Y}_{0.3}\text{O}_3$ (scale bar: 5 nm).

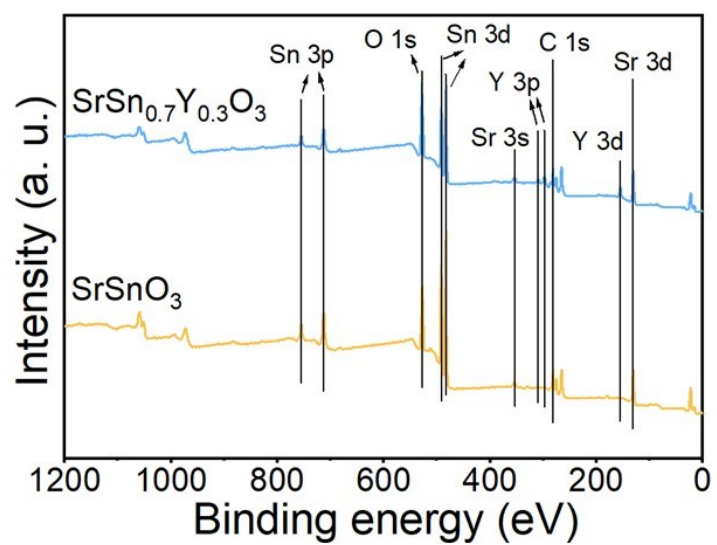


Fig. S3 Wide-scan XPS spectra of SrSnO_3 and $\text{SrSn}_{0.7}\text{Y}_{0.3}\text{O}_3$.

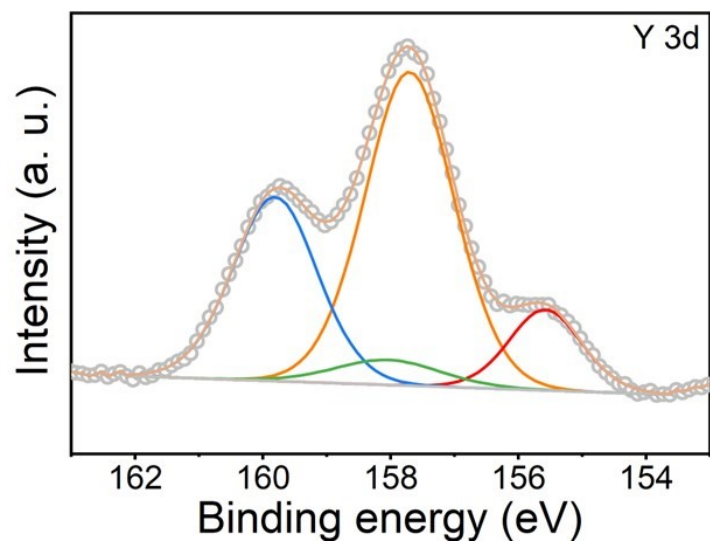


Fig. S4 Y 3d XPS spectra of $\text{SrSn}_{0.7}\text{Y}_{0.3}\text{O}_3$.

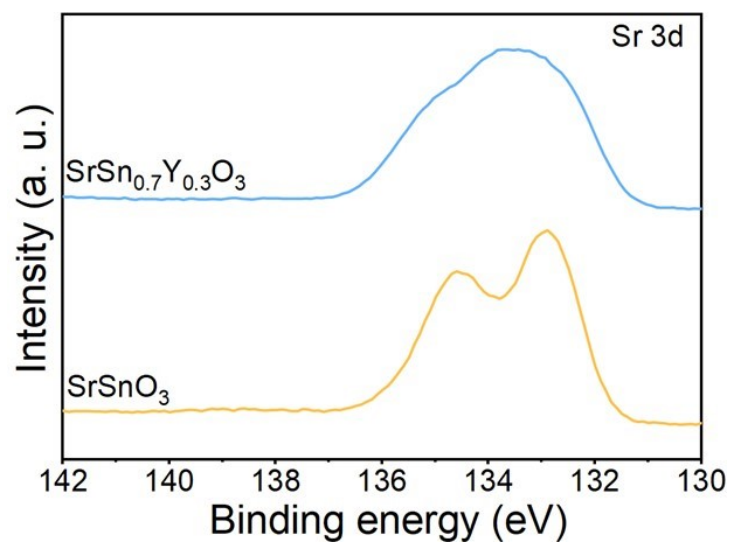


Fig. S5 Sr 3d XPS spectra of SrSnO₃ and SrSn_{0.7}Y_{0.3}O₃.

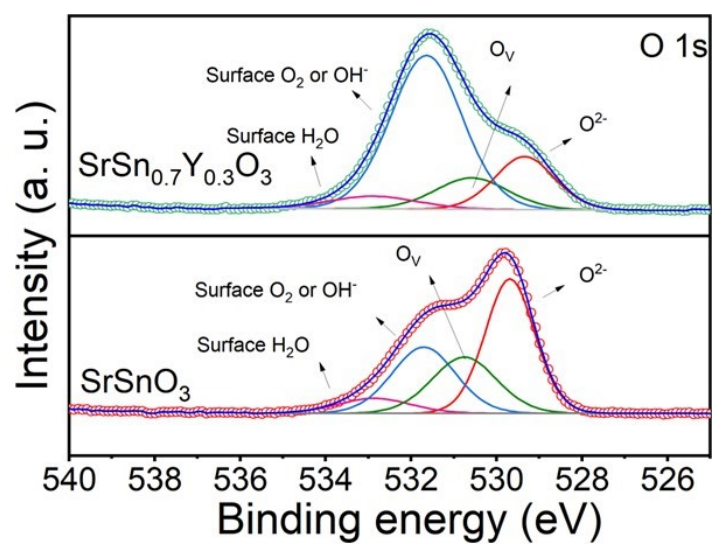


Fig. S6 O 1s XPS spectra of SrSnO_3 and $\text{SrSn}_{0.7}\text{Y}_{0.3}\text{O}_3$.

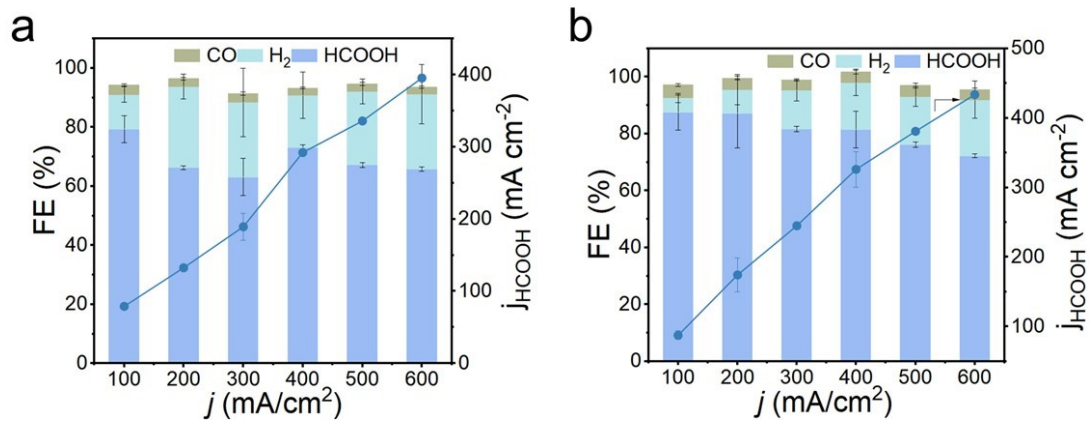


Fig. S7 FEs for various products and current densities of HCOOH over (a) SrSnO₃ and (b) SrSn_{0.7}Y_{0.3}O₃ at different current densities (from 100 to 600 mA cm⁻²) in 1 M KOH.

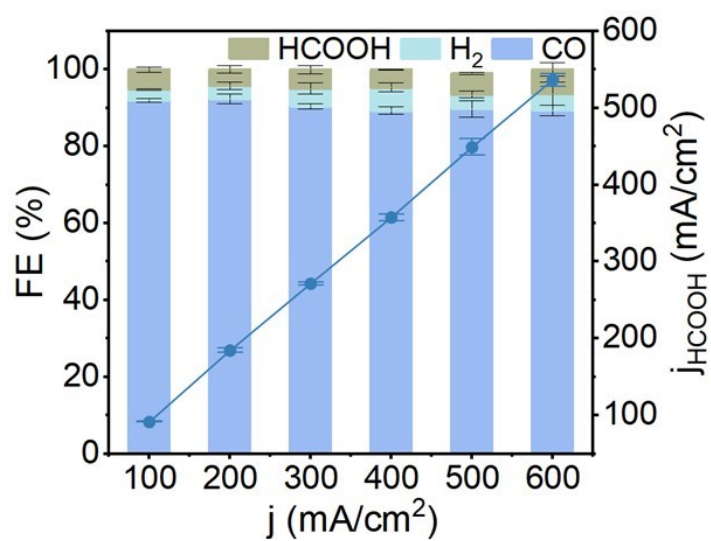


Fig. S8 FEs for various products and current densities of HCOOH over SrSnO_3 catalyst at different applied current densities (from 100 to 600 mA cm^{-2}) in 0.005 M H_2SO_4 + 3 M KCl.

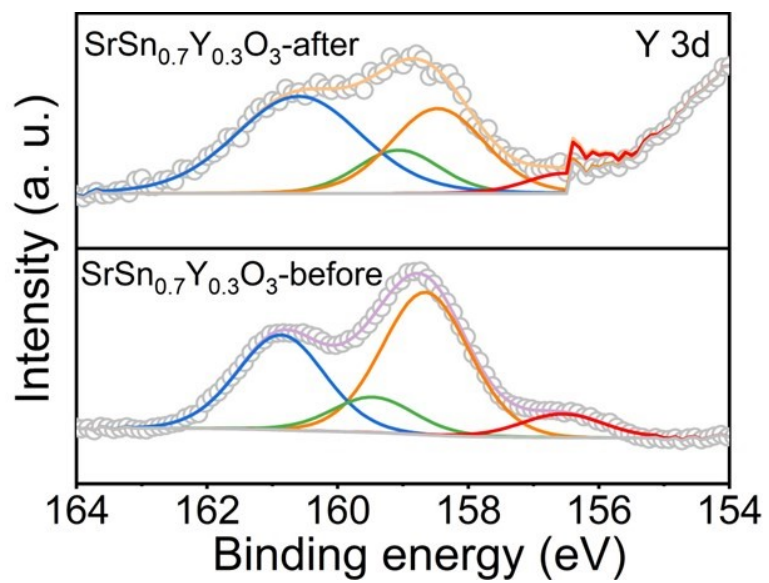


Fig. S9 Y 3d XPS spectra of SrSn_{0.7}Y_{0.3}O₃ catalysts before and after electrolysis.

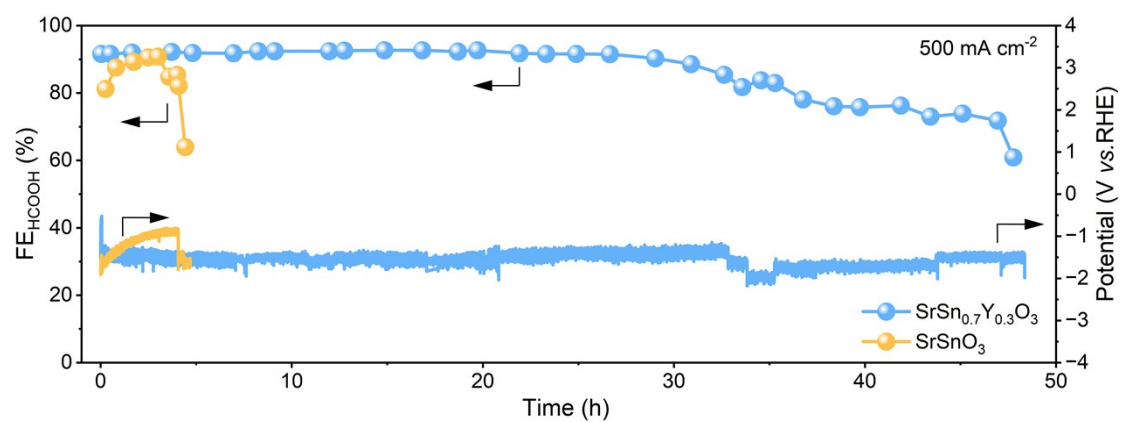


Fig. S10. Durability performance of SrSn_{0.7}Y_{0.3}O₃ and SrSnO₃ in 0.005 M H₂SO₄ + 1.2 M KCl (at 500 mA cm⁻²).

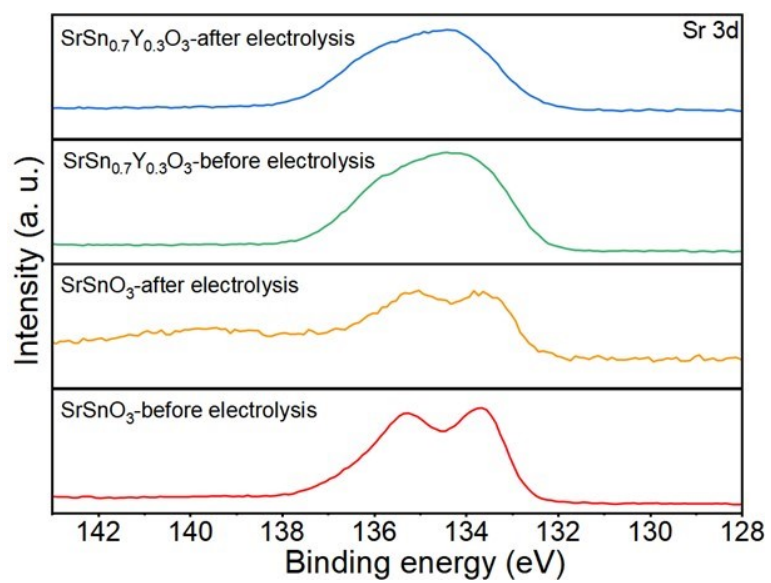


Fig. S11 Sr 3d XPS spectra of SrSnO₃ and SrSn_{0.7}Y_{0.3}O₃ catalysts before and after electrolysis.

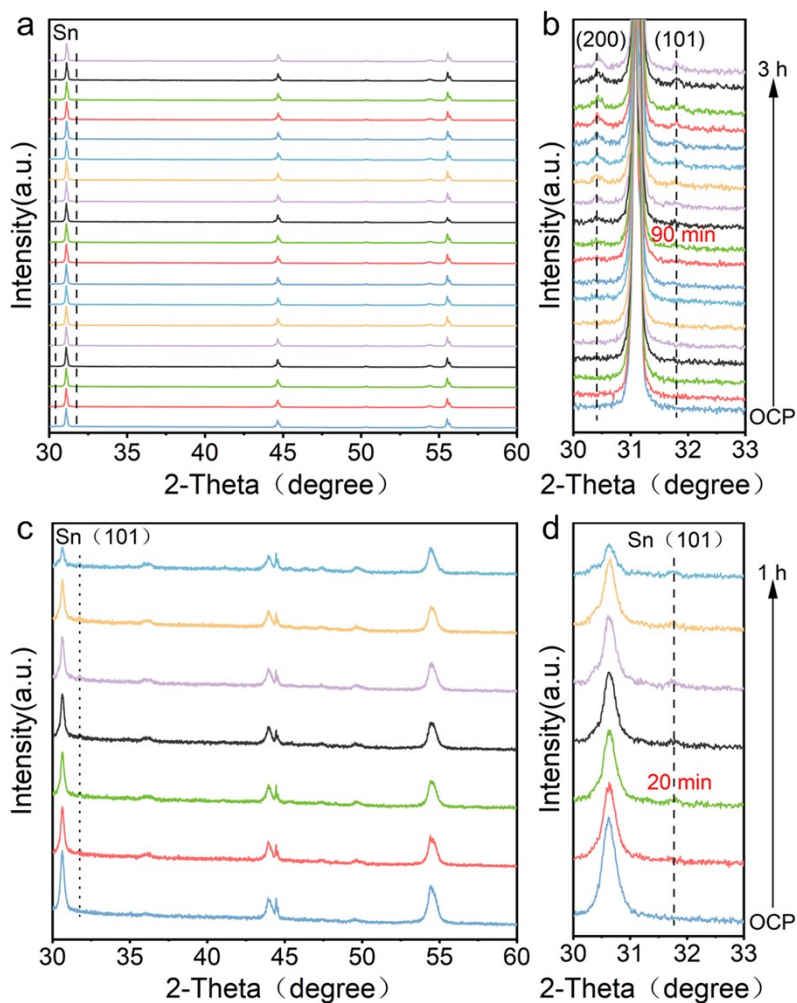


Fig. S12 *In situ* XRD patterns of SrSnO_3 and $\text{SrSn}_{0.7}\text{Y}_{0.3}\text{O}_3$ during CO_2RR . (a) *In situ* XRD patterns of SrSnO_3 during CO_2RR . (b) Enlarged view of the Sn-related diffraction region for SrSnO_3 . (c) *In situ* XRD patterns of $\text{SrSn}_{0.7}\text{Y}_{0.3}\text{O}_3$ during CO_2RR . (d) Enlarged view of the Sn-related diffraction region for $\text{SrSn}_{0.7}\text{Y}_{0.3}\text{O}_3$.

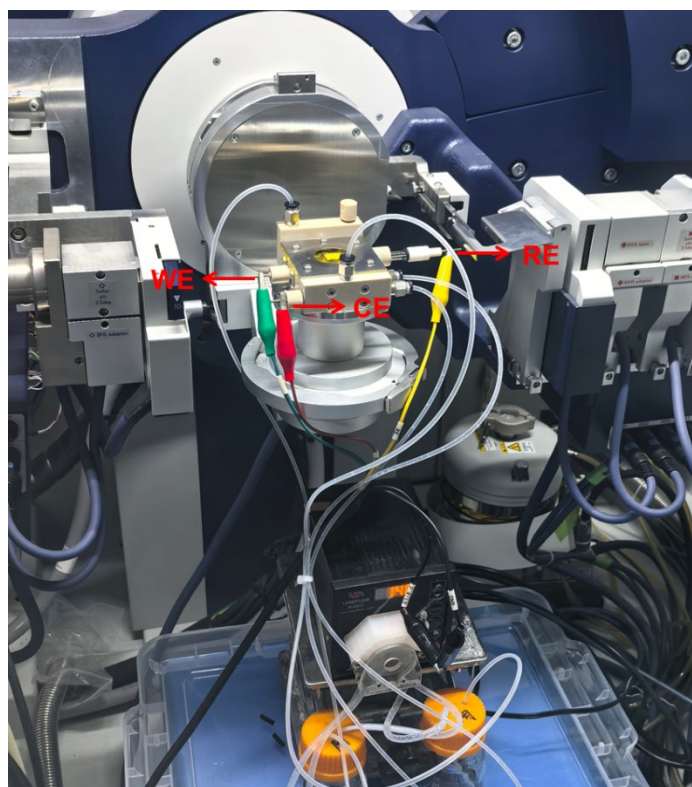


Fig. S13 Photograph of the *in situ* XRD setup for CO₂RR measurements.

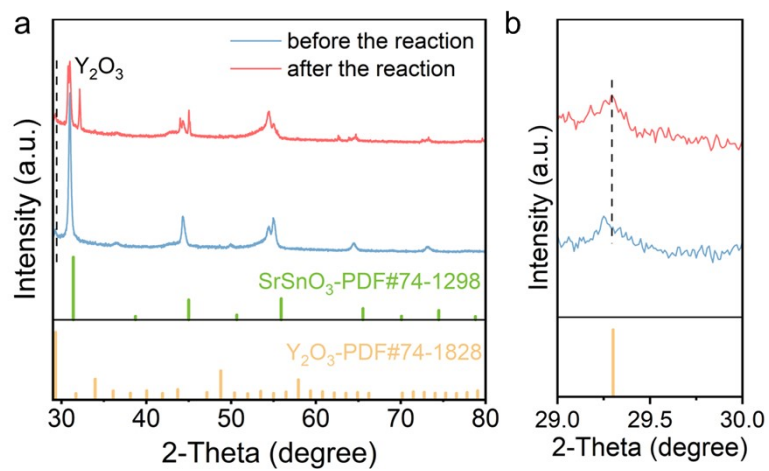


Fig. S14 (a) XRD patterns and (b) enlarged view of SrSn_{0.7}Y_{0.3}O₃ before and after CO₂RR electrolysis.

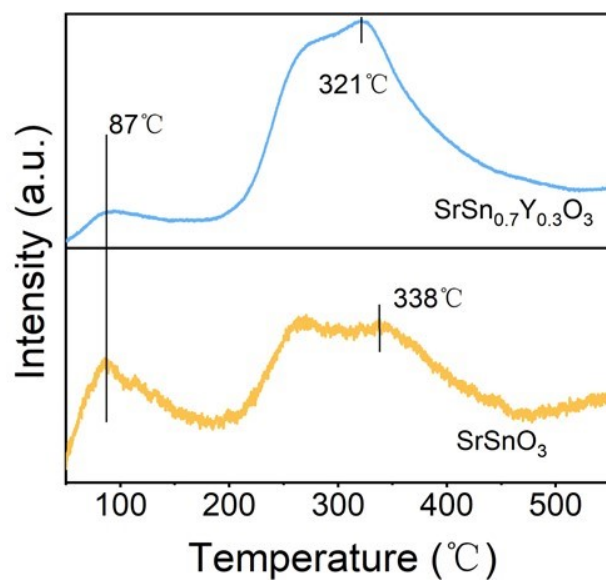


Fig. S15 CO₂-TPD profiles of SrSnO₃ and SrSn_{0.7}Y_{0.3}O₃ catalysts.

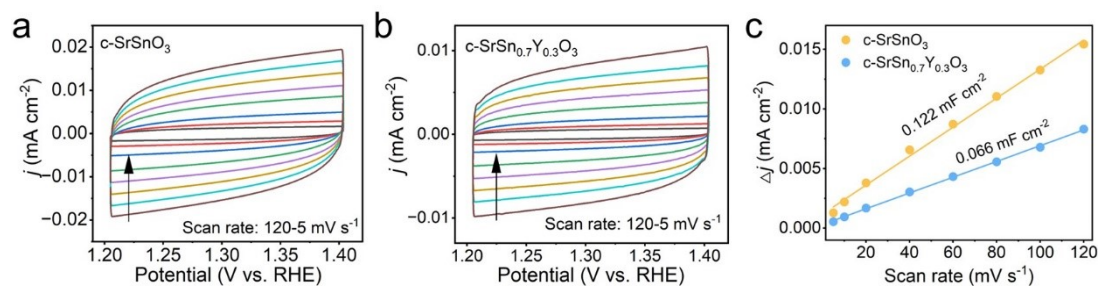


Fig. S16 The ECSA measurements of (a) $c\text{-SrSnO}_3$ and (b) $c\text{-SrSn}_{0.7}\text{Y}_{0.3}\text{O}_3$. (c) The measured C_{dl} for $c\text{-SrSnO}_3$ and $c\text{-SrSn}_{0.7}\text{Y}_{0.3}\text{O}_3$.

Table S1 Refined parameters of the SrSnO₃ and SrSn_{0.7}Y_{0.3}O₃ samples from Rietveld refinement analysis using the corresponding XRD data.

Phase	Weight fraction	Space group	Lattice parameters	Reliability factors
Cubic perovskite	100 wt%	<i>Pm-3m</i>	a= 4.03313 Å b= 4.03313 Å c= 4.03313 Å	R _{wp} =13.1% R _p =9.75% χ ² =7.36

SrSnO₃

Phase	Weight fraction	Space group	Lattice parameters	Reliability factors
Cubic perovskite	100 wt%	<i>Pm-3m</i>	a= 4.08838 Å b= 4.08838 Å c= 4.08838 Å	R _{wp} =12.8% R _p =9.71% χ ² =7.69

SrSn_{0.7}Y_{0.3}O₃

Table S2 Comparison of the long-term stability for HCOOH production over the reported catalysts.

Catalyst	Electrolyte	Potential (V vs. RHE)	FE _{HCOOH} (%)	j _{HCOOH} (mA cm ⁻²)	Stability (h)	Ref.
SrSn _{0.7} Y _{0.3} O ₃	0.005 M H ₂ SO ₄ + 0.5 M KCl	-1.45	89.3	178.6	180	This work
R-CuSnO ₃	0.1 M H ₂ SO ₄ + 0.5 M K ₂ SO ₄ (pH = 1)	-1	80	160	8	1
Sn-SACs	H ₂ SO ₄ + 0.5 M K ₂ SO ₄ (pH = 3)	-1.4	90	135	18	2
NU-1000-Sn	H ₂ SO ₄ + 0.005 M K ₂ SO ₄ (pH = 1.67)	-1.8	95	247	15	3
Sn(S)-H	H ₂ SO ₄ + 0.5 M K ₂ SO ₄ (pH = 3)	-2	85	340	13.5	4
Sn-C/SiO ₂ -3	H ₂ SO ₄ + 0.5 M K ₂ SO ₄ (pH = 2)	-1.8	90	360	45	5
SnS-NRs	phosphate buffer (pH = 2)	N.A.	92	184	48	6
SnO _x -300	0.5 M KHCO ₃	-0.98	88.6	15	18	7
SnO ₂ -Bi ₂ O ₃ /C	1 M KOH	-1.29	91	200.2	48	8
In/N-dG	1 M KOH	-3.7	93.3	485.16	20	9
In ₂ O ₃	0.05 M H ₂ SO ₄ + 0.05 M K ₂ SO ₄	-2.51	98.9	296.7	100	10
ZnIn ₂ S ₄	1M KHCO ₃	N.A.	97	291	60	11

Reference:

1. T. Fan, J. Zhang, X. Zhang, M. Wang, X. Yi, Y. Lum and Z. Chen, *Nano Energ.*, 2024, **130**, 110135.
2. B. Sun, Z. Li, D. Xiao, H. Liu, K. Song, Z. Wang, Y. Liu, Z. Zheng, P. Wang, Y. Dai, B. Huang, A. Thomas and H. Cheng, *Angew. Chem. Int. Ed.*, 2024, **63**, e202318874.
3. H. Xue, Z. H. Zhao, P. Q. Liao and X. M. Chen, *J. Am. Chem. Soc.*, 2023, **145**, 16978-16982.
4. H. Shen, H. Jin, H. Li, H. Wang, J. Duan, Y. Jiao and S. Z. Qiao, *Nat. Commun.*, 2023, **14**, 2843.
5. Z. Wang, H. Li, T. Dong, Y. Geng, X. Tian, R. Chang, J. Lai, S. Feng and L. Wang, *Chem. Eng. J.*, 2024, **489**, 151238.
6. Y. Wang, H. Xu, E. P. Delmo, J. Jang, Y. Zhang, T. Li, X. Qiu, Z. Ying, P. Gao and M. Shao, *ACS Catal.*, 2025, **15**, 5651-5663.
7. T. Gao, A. Kumar, Z. Shang, X. Duan, H. Wang, S. Wang, S. Ji, D. Yan, L. Luo, W. Liu and X. Sun, *Chin. Chem. Lett.*, 2019, **30**, 2274-2278.
8. X. Wang, W. Wang, J. Zhang, H. Wang, Z. Yang, H. Ning, J. Zhu, Y. Zhang, L. Guan, X. Teng, Q. Zhao and M. Wu, *Chem. Eng. J.*, 2021, **426**, 131867.
9. J. Bi, P. Li, J. Liu, Y. Wang, X. Song, X. Kang, X. Sun, Q. Zhu and B. Han, *Angew. Chem. Int. Ed.*, 2023, **62**, e202307612.
10. Z. Wang, D. Liu, C. Xia, X. Shi, Y. Zhou, Q. Liu, J. Huang, H. Wu, D. Zhu, S. Zhang, J. Li, P. Deng, A. S. Vasenko, B. Y. Xia and X. Tian, *Nat. Commun.*, 2025, **16**, 1754.
11. L. P. Chi, Z. Z. Niu, X. L. Zhang, P. P. Yang, J. Liao, F. Y. Gao, Z. Z. Wu, K. B. Tang and M. R. Gao, *Nat. Commun.*, 2021, **12**, 5835.