

Electronic Supplementary Information

**Highly active Pt/In₂O₃ catalyst for CO₂ hydrogenation to methanol
with enhanced stability**

Kaihang Sun,^{a,b} Ning Rui,^{a,b} Zhitao Zhang,^{a,b} Zeyu Sun,^{a,b} Qingfeng Ge,^c and Chang-jun Liu^{a,b*}

a. Tianjin Co-Innovation Center of Chemical Science & Engineering, Tianjin University, Tianjin 300072, China.

b. School of Chemical Engineering and Technology, Tianjin University, Tianjin 300072, China.

c. Department of Chemistry and Biochemistry, Southern Illinois University, Carbondale, Illinois 62901, United States.

Table S1. Comparison of typical reported catalysts for CO₂ hydrogenation to methanol.

Catalyst	T [°C]	P [MPa]	GHSV [cm ³ h ⁻¹ g _{cat} ⁻¹]	X _{CO2} [%]	S _{MeOH} [%]	Methanol formation rate [g _{MeOH} h ⁻¹ g _{cat} ⁻¹]	Ref.
CuIn@SiO ₂	280	3.0	20000	9.8	78.1	0.438	S1
Cu/AlCeO	260	3.0	14400	n/a	n/a	0.381	S2
CuNi ₂ /CeO ₂	260	3.0	6000	17.8	78.8	0.579	S3
Cu-ZnO-ZrO ₂	240	3.0	2400	18.2	41.6	0.122	S4
Cu-Zn-Ga/SiO ₂	270	2.0	18000	5.6	99.5	0.349	S5
Ni/In ₂ O ₃	300	5.0	21000	18.5	54.0	0.550	S6
Ni/In ₂ O ₃	275	5.0	21000	11.9	64.6	0.430	S6
Ni/In ₂ O ₃	250	5.0	21000	5.4	69.4	0.213	S6
Rh/In ₂ O ₃	300	5.0	21000	17.1	56.1	0.545	S7
Rh/In ₂ O ₃	275	5.0	21000	9.3	72.6	0.385	S7
Rh/In ₂ O ₃	250	5.0	21000	4.0	82.0	0.188	S7
Pd/Ga ₂ O ₃	250	5.0	18000	19.6	10.1	0.128	S8
Ga ₂ O ₃ -Pd/SiO ₂	250	3.0	7800 ^a	n/a	70.0	0.253	S9
Pd/In ₂ O ₃	300	5.0	21000	20.5	72.1	0.885	S10
Pd/In ₂ O ₃ .CP	280	5.0	48000	9.7	75.0	0.960	S11
Pd/CeO ₂	230	3.0	2240	3.0	92.0	0.022	S12
Pt/film/In ₂ O ₃	30	0.1	4800 ^b	37.0	62.6	0.355	S13
Pt/MoO ₃ /TiO ₂	150	6.0	n/a	n/a	ca. 90.0	0.017 ^b	S14
UiO-67-Pt	170	0.8	6000	1.5	19.0	0.0024 ^b	S15
Pt/Nb ₂ O ₅	300	0.5	30000	6.0	0.8 ^d	n/a	S16
ZnO/ZrO ₂	315	5.0	24000	10.0	90.0	ca. 16.0 ^c	S17
In ₂ O ₃ /ZrO ₂	300	5.0	20000	5.2	99.8	0.295	S18
In ₂ O ₃	330	4.0	15000	7.1	39.7	0.118	S19
In ₂ O ₃	300	5.0	21000	9.4	62.7	0.335	This work
Pt/In ₂ O ₃	250	5.0	21000	6.6	84.0	0.316	This work
Pt/In ₂ O ₃	275	5.0	21000	11.9	74.0	0.499	This work
Pt/In ₂ O ₃	300	5.0	21000	17.6	54.0	0.542	This work

^a the unit for this work is h⁻¹;^b calculated by the catalytic data in the references if not given directly;^c the unit here is mg m⁻² h⁻¹;^d tested at 280 °C.

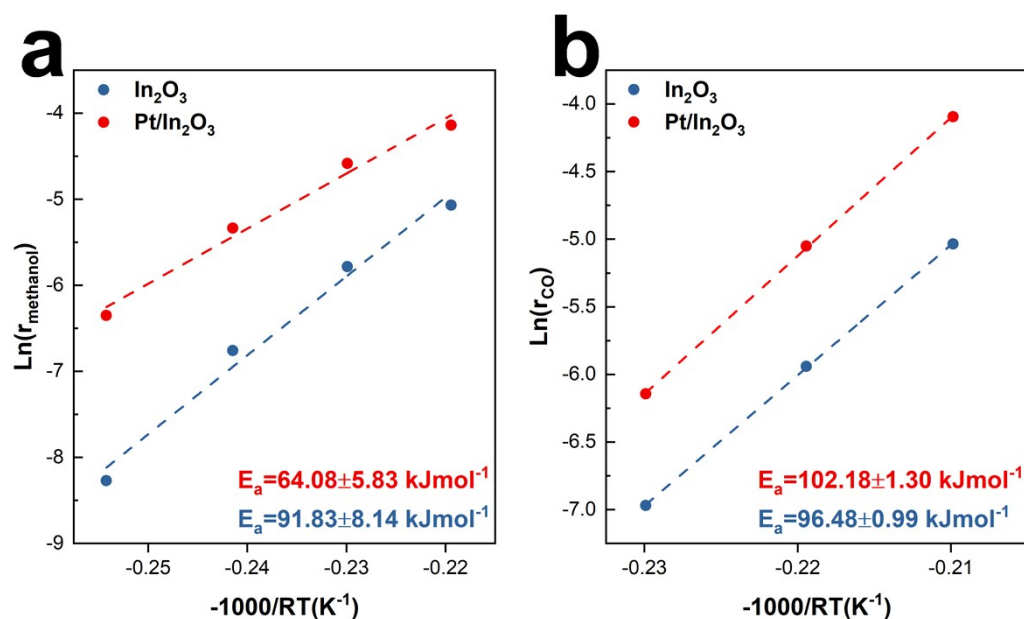


Figure S1. Apparent activation energy for methanol (a) and CO (b) production over the $\text{Pt/In}_2\text{O}_3$ and the pure In_2O_3 catalysts.

References

- S1 Z. Shi, Q. Tan and D. Wu, *AIChE J.*, 2018, **65**, 1047-1058.
- S2 S. Li, L. Guo and T. Ishihara, *Catal. Today*, 2020, **339**, 352-361.
- S3 Q. Tan, Z. Shi and D. Wu, *Ind. Eng. Chem. Res.*, 2018, **57**, 10148-10158.
- S4 G. Wang, D. Mao, X. Guo and J. Yu, *Int. J. Hydrog. Energy*, 2019, **44**, 4197-4207.
- S5 J. Toyir, P. R. r. de la Piscina, J. L. G. Fierro and N. Homs, *Appl. Catal. B*, 2001, **29**, 207-215.
- S6 X. Jia, K. Sun, J. Wang, C. Shen and C.-j. Liu, *J. Energy Chem.*, 2020, **50**, 409-415.
- S7 J. Wang, K. Sun, X. Jia and C.-j. Liu, *Catal. Today*, 2020, DOI: 10.1016/j.cattod.2020.05.020.
- S8 T. Fujitani, M. Saito, Y. Kanai, T. Watanabe, J. Nakamura and T. Uchijima, *Appl. Catal. A*, 1995, **125**, L199-L202.
- S9 S. E. Collins, D. L. Chiavassa, A. L. Bonivardi and M. A. Baltanás, *Catal. Lett.*, 2005, **103**, 83-88.
- S10 N. Rui, Z. Wang, K. Sun, J. Ye, Q. Ge and C.-j. Liu, *Appl. Catal. B*, 2017, **218**, 488-497.
- S11 M. S. Frei, C. Mondelli, R. García-Muelas, K. S. Kley, B. Puértolas, N. López, O. V. Safonova, J. A. Stewart, D. Curulla Ferré and J. Pérez-Ramírez, *Nat. Commun.*, 2019, **10**, 3377.
- S12 L. Fan and K. Fujimoto, *J. Catal.*, 1994, **150**, 217-220.
- S13 Y.-L. Men, Y. Liu, Q. Wang, Z.-H. Luo, S. Shao, Y.-B. Li and Y.-X. Pan, *Chem. Eng. Sci.*, 2019, **200**, 167-175.
- S14 T. Toyao, S. Kayamori, Z. Maeno, S. M. A. H. Siddiki and K.-i. Shimizu, *ACS Catal.*, 2019, **9**, 8187-8196.
- S15 E. S. Gutterød, A. Lazzarini, T. Fjermestad, G. Kaur, M. Manzoli, S. Bordiga, S. Svelle, K. P. Lillerud, E. Skúlason, S. Øien-Ødegaard, A. Nova and U. Olsbye, *J. Am. Chem. Soc.*, 2020, **142**, 999-1009.
- S16 S. B. T. Tran, H. Choi, S. Oh and J. Y. Park, *Catal. Lett.*, 2019, **149**, 2823-2835.
- S17 J. Wang, G. Li, Z. Li, C. Tang, Z. Feng, H. An, H. Liu, T. Liu and C. Li, *Sci. Adv.*, 2017, **3**.
- S18 O. Martín, A. J. Martín, C. Mondelli, S. Mitchell, T. F. Segawa, R. Hauert, C. Drouilly, D. Curulla-Ferré and J. Pérez-Ramírez, *Angew. Chem.-Int. Edit.*, 2016, **55**, 6261-6265.
- S19 K. Sun, Z. Fan, J. Ye, J. Yan, Q. Ge, Y. Li, W. He, W. Yang and C.-j. Liu, *J. CO₂ Util.*, 2015, **12**, 1-6.