

Supporting Information for

Synergistic Effect of Scattered Rare Metals on Pt/CeO₂ for Propane

Oxidative Dehydrogenation with CO₂

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Experimental Materials

Ce (NH₄)(NO₃)₆, Urea, H₂PtCl₆·6H₂O (Pt > 37.5%), SnCl₂·2H₂O, Ga(NO₃)₃·xH₂O, InCl₃·4H₂O purchased from Shanghai Macklin Biochemical Co. Ltd. Ethanol was purchased from Sinopharm Chemical Reagent Co., Ltd. The ultrapure water (>18.2 MΩ) used in the experiments was homemade from a laboratory-configured water purifier.



Figure S1. Physical diagram of catalysts.

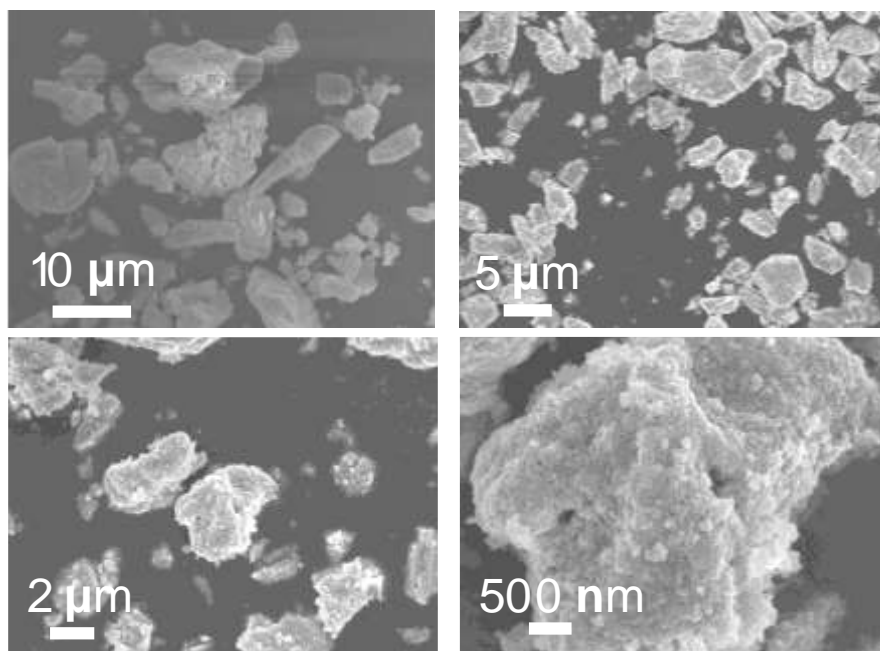


Figure S2. SEM images of PtGa/CeO₂.

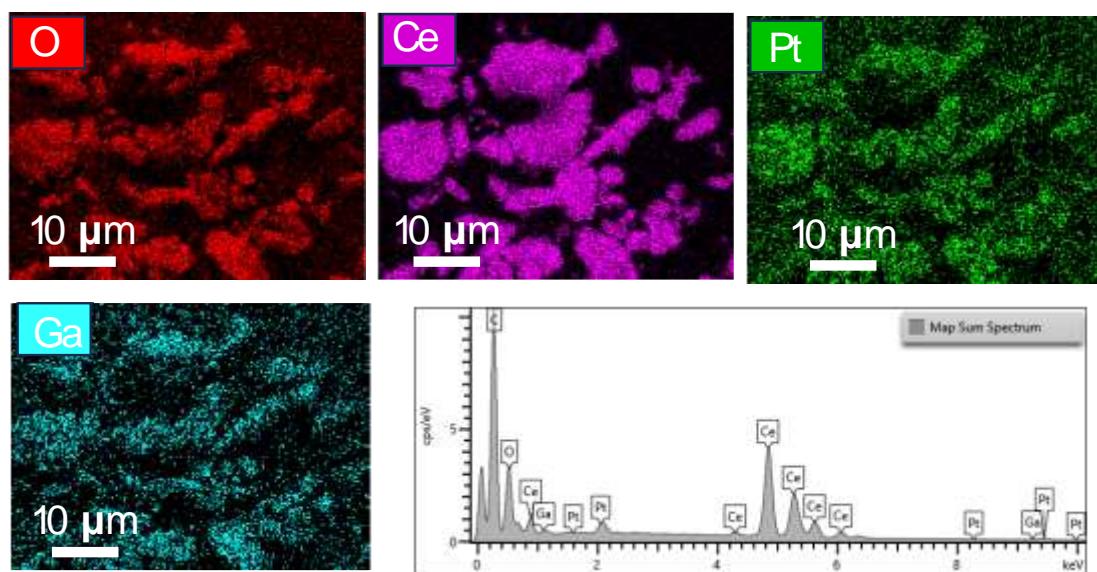


Figure S3. SEM-EDS elemental mappings of PtGa/CeO₂.

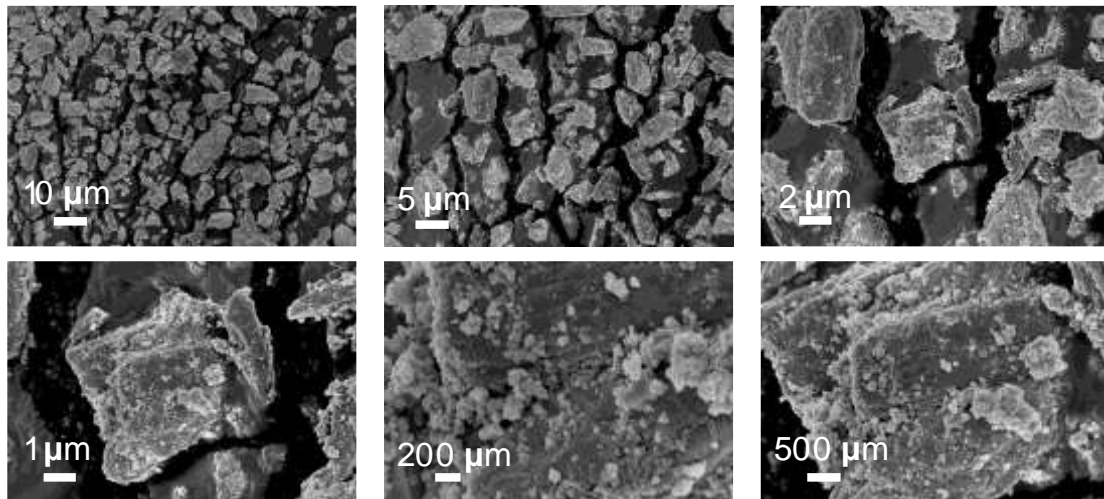


Figure S4. SEM images of PtIn/CeO₂.

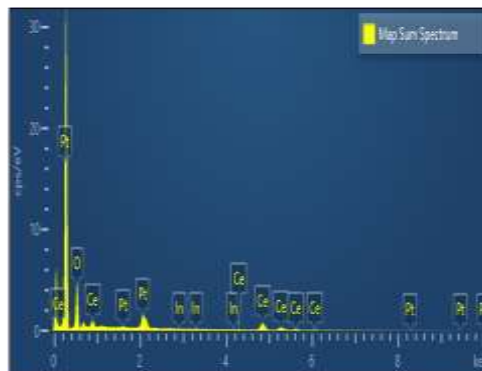


Figure S5. Map sum spectrum of elements of PtIn/CeO₂.

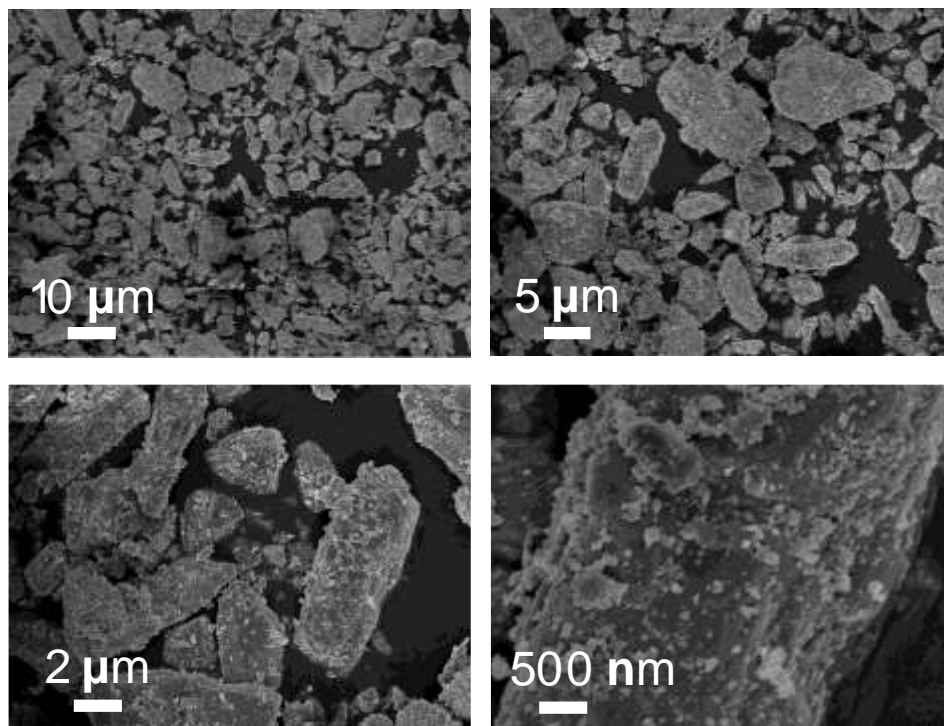


Figure S6. SEM iamges of PtSn/CeO₂.

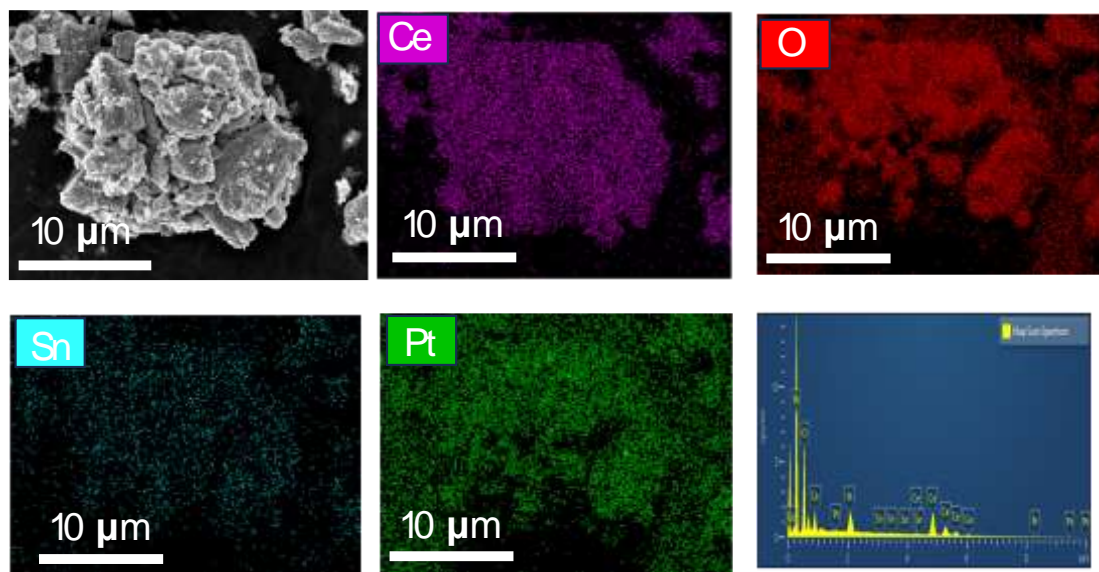


Figure S7. SEM-EDS elemental mappings of PtSn/CeO₂.

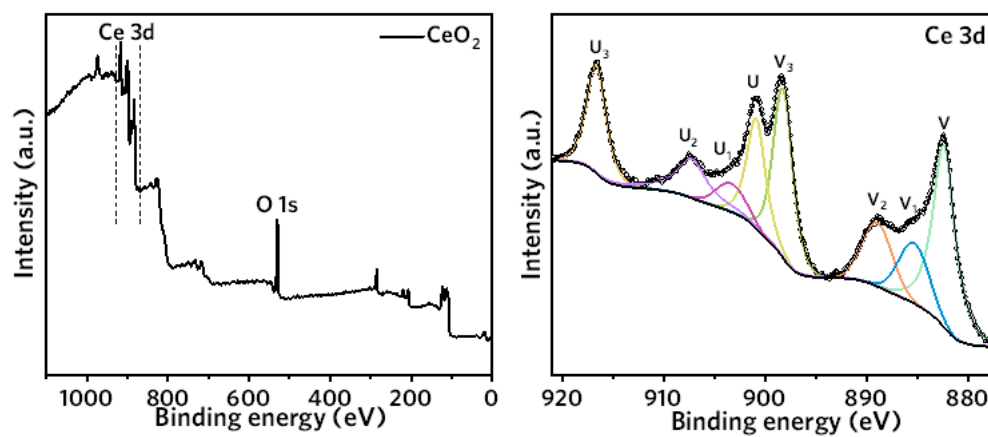


Figure S8. Wide spectra and Ce 3d high-resolution XPS spectra of CeO₂.

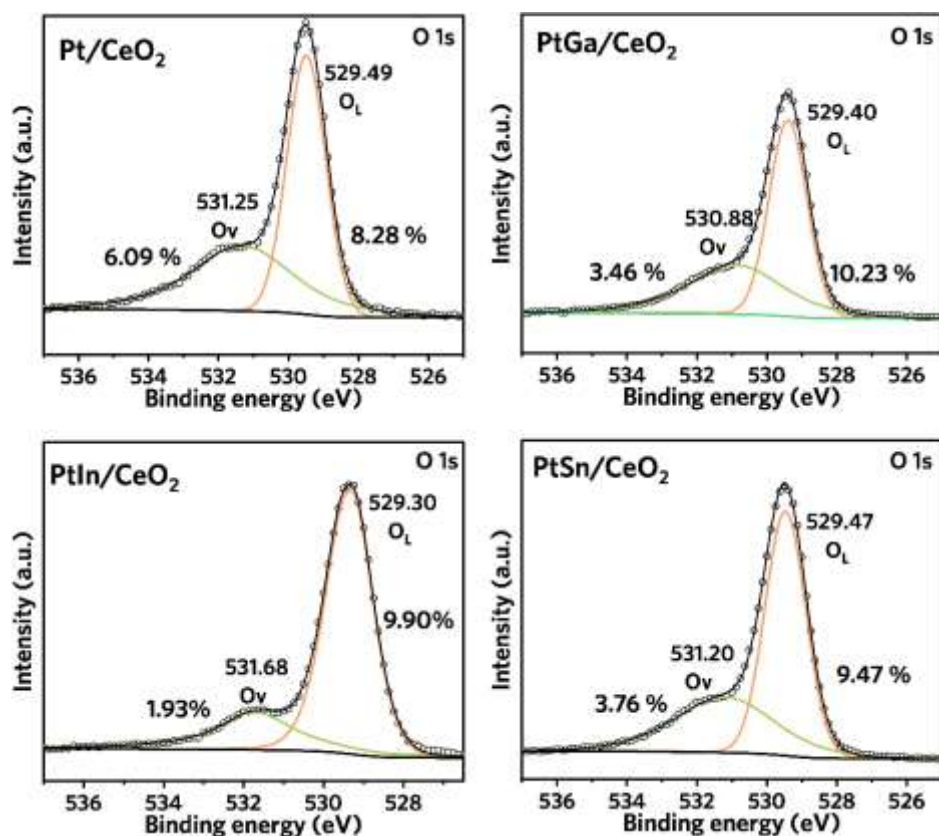


Figure S9. O 1s high-resolution XPS spectra of Pt/CeO₂, PtGa/CeO₂, PtIn/CeO₂ and PtSn/CeO₂.

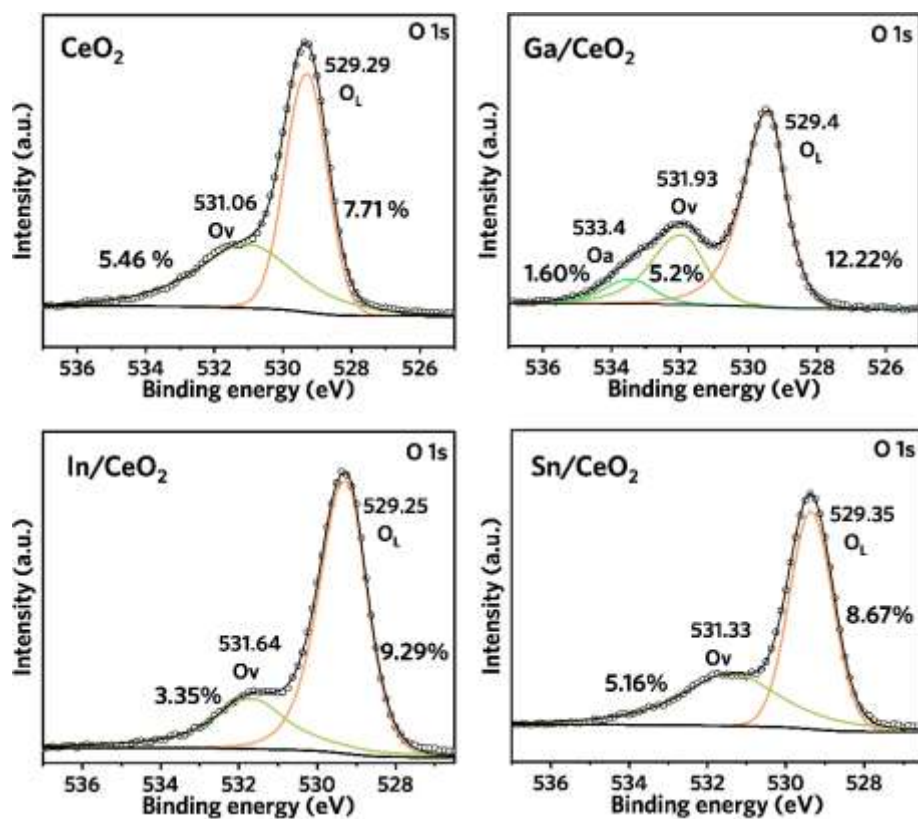


Figure S10. O 1s high-resolution XPS spectra of CeO₂, Ga/CeO₂, In/CeO₂ and Sn/CeO₂.

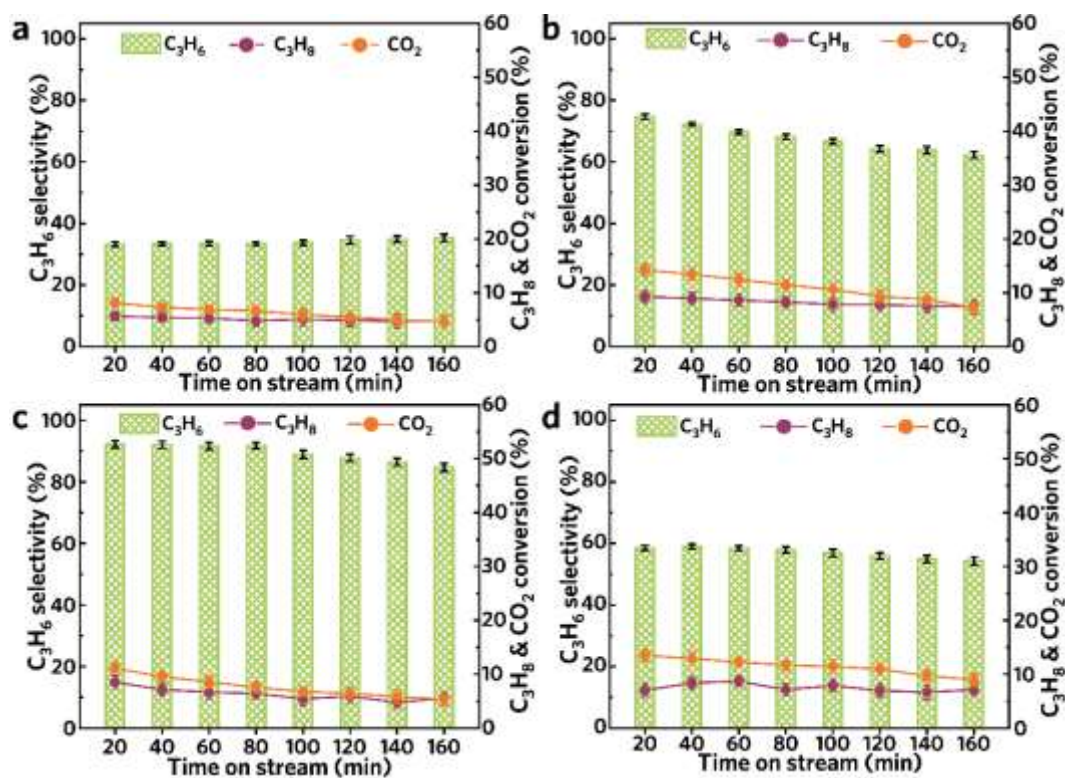


Figure S11. (a-d) The CO₂-ODP performance of CeO₂, Ga/CeO₂, Sn/CeO₂ and In/CeO₂, respectively.

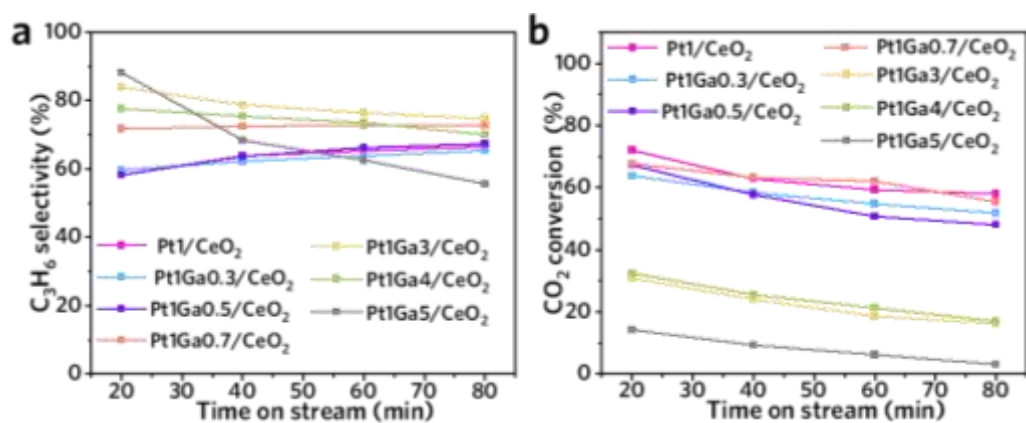


Figure S12. (a-b) The selectivity of C₃H₆ and conversion of CO₂ with time varies over Pt₁Ga_x/CeO₂.

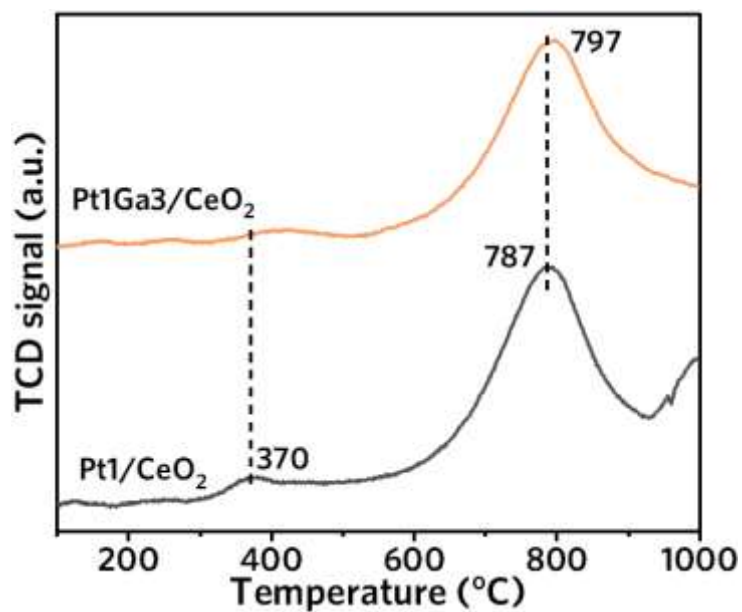


Figure S13. H₂-TPR profiles of Pt1/CeO₂ and Pt1Ga₃/CeO₂.

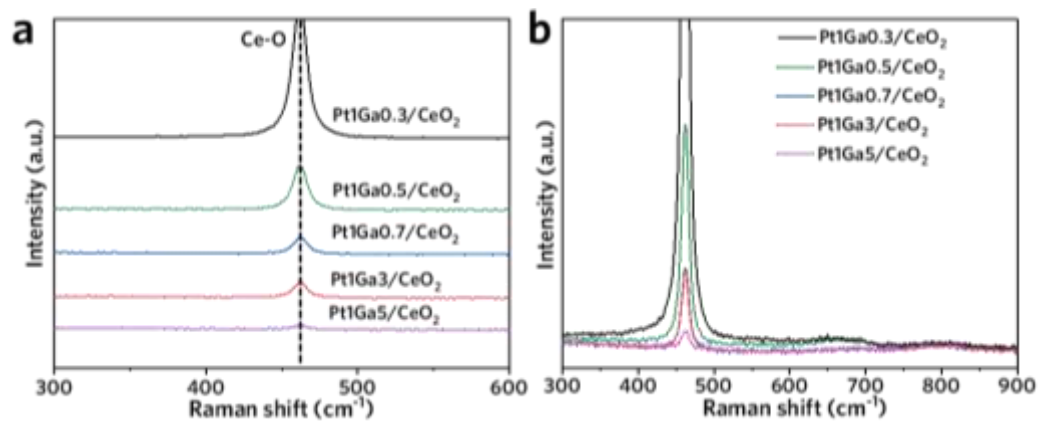


Figure S14. (a-b) Raman spectra at different regions of resh Pt1Ga_x/CeO₂.

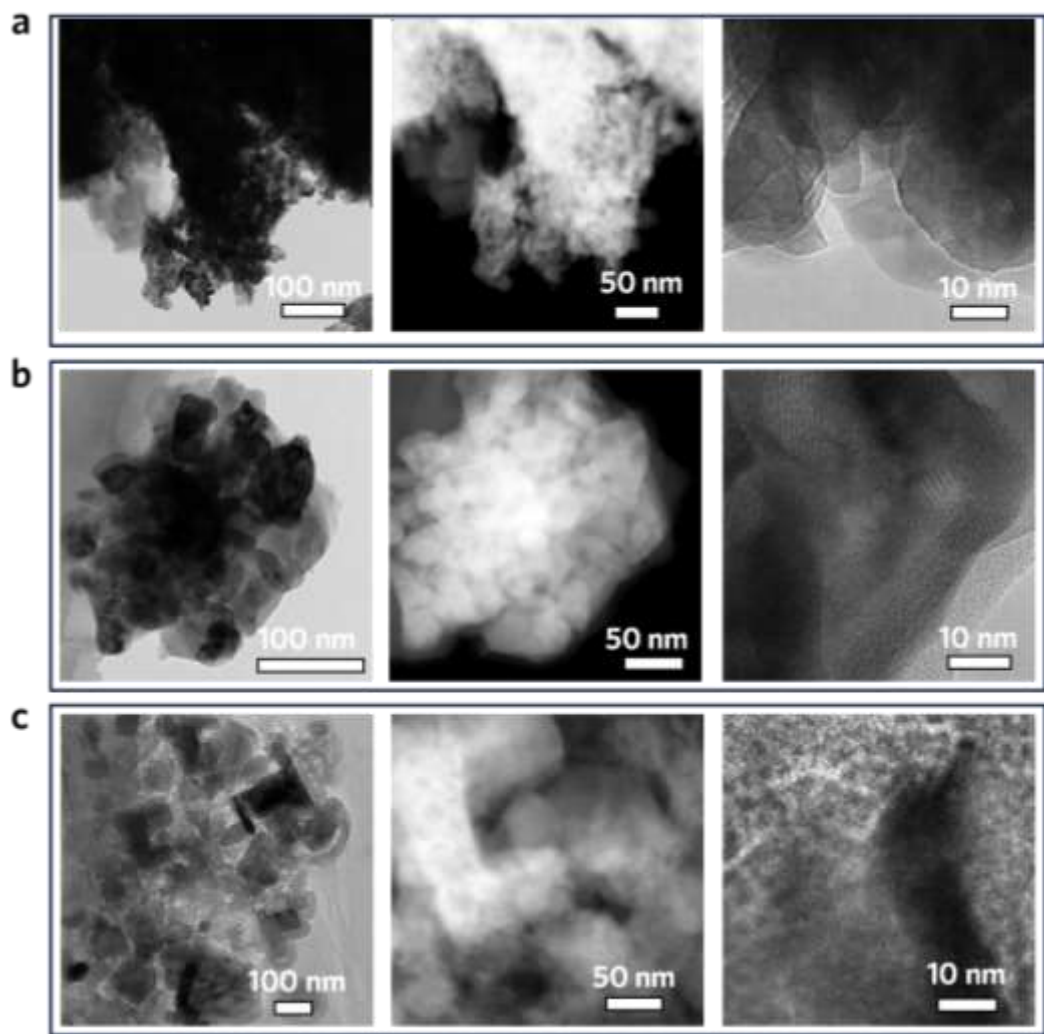


Figure S15. (a-c) TEM and HRTEM images of Pt1Ga0.5/CeO₂, Pt1Ga0.7/CeO₂ and Pt1Ga5/CeO₂, respectively.

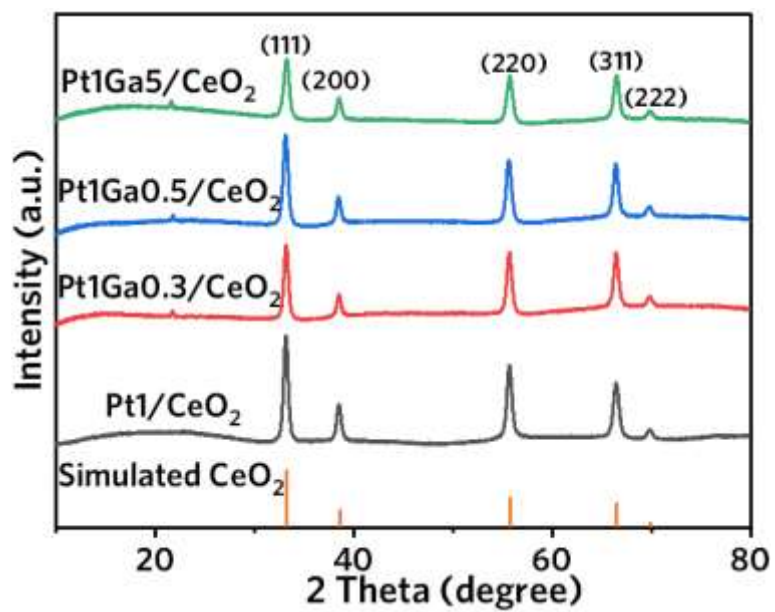


Figure S16. XRD spectra fresh Pt1Gax/CeO₂.

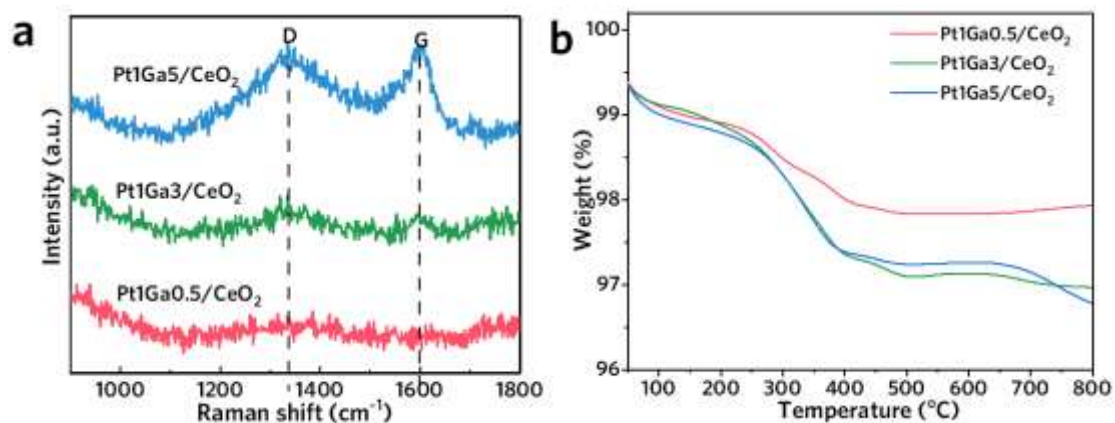


Figure S17. The Raman spectra and TG -DSC profiles of spent Pt1Gax/CeO₂ catalysts after CO₂-ODP (TOS of 80 min).

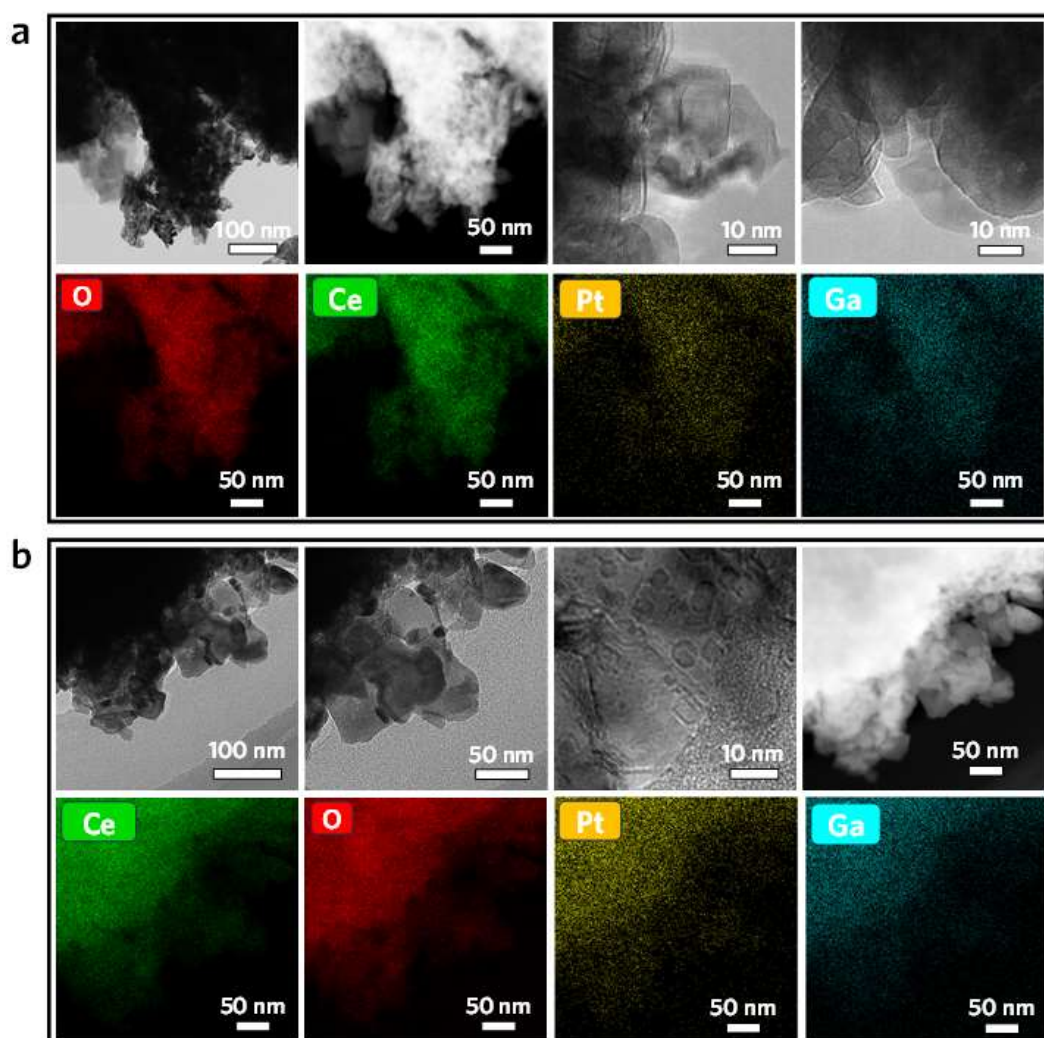


Figure S18. (a-b) The TEM images and corresponding elements Mapping of Pt1Ga0.5/CeO₂ before and after CO₂-ODP reaction.

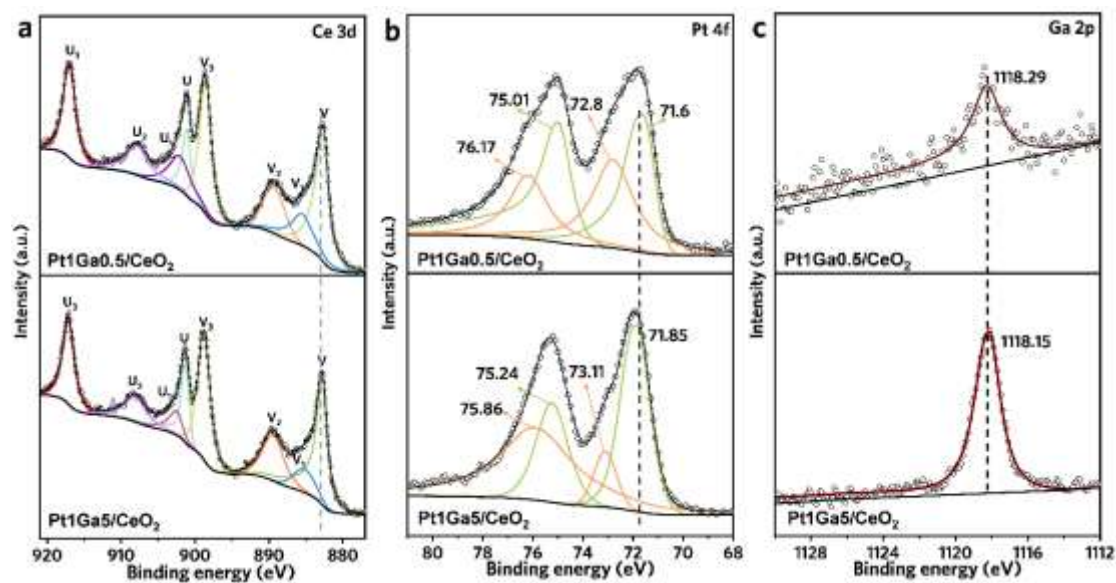


Figure S19. (a-e) The Ce 3d, Pt 4f, Ga 2p XPS of Pt1Ga0.5/CeO₂ and Pt1Ga5/CeO₂.

Table S1. The amount of Pt and scattered rare metals in catalysts.

Catalysts	Pt content (wt%)	Ga content (wt%)	In content (wt%)	Sn content (wt%)
Pt1/CeO ₂	1.09	-	-	-
Pt1Ga0.3/CeO ₂	1.06	0.31	-	-
Pt1Ga0.5/CeO ₂	1.08	0.49	-	-
Pt1Ga0.7/CeO ₂	0.97	0.68	-	-
Pt1Ga1/CeO ₂	0.94	0.96	-	-
Pt1Ga3/CeO ₂	0.96	3.12	-	-
Pt1Ga5/CeO ₂	0.99	5.2	-	-
Pt1In3/CeO ₂	1.28	-	3.10	-
Pt1Sn3/CeO ₂	0.93	-	-	2.97

Table S2. The summary of the pore structure of catalysts.

Samples	S_{BET}^a (m²/g)	M_{BET}^b (m²/g)	E_{BET}^c (m²/g)	Adsorp. pore diameter(nm)	Desorp. pore diameter(nm)
CeO ₂	14.9	0.2	14.7	4.1	3.5
Pt/CeO ₂	13.8	0.03	13.7	3.7	3.2
PtGa/CeO ₂	13.1	0	13.7	3.9	3.4
PtIn/CeO ₂	12.3	0	12.5	4.1	3.5
PtSn/CeO ₂	12.5	0	12.7	3.9	3.4

a

Surface area, derived from BET equation;

b

Micropore area, derived from BET equation;

c

External surface area, derived from BET equation.