Supplementary Information

Synthesis of glyceric acid by mixed metal oxide supported AuPt alloy catalyst in mild condition

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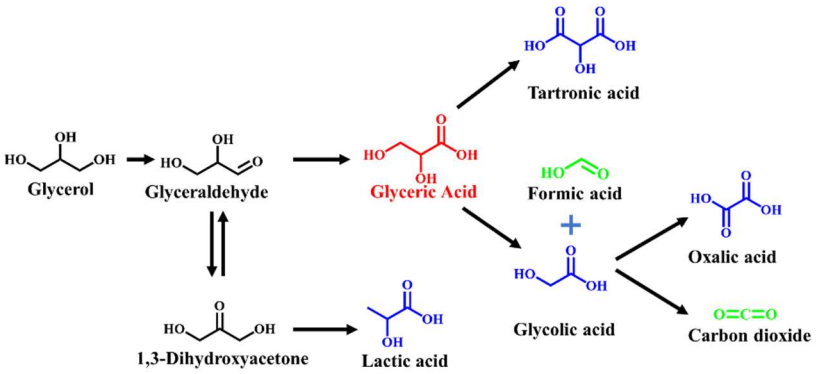
Supplementary figures and tables



Scheme S1. Possible reaction pathways for glycerol oxidation.

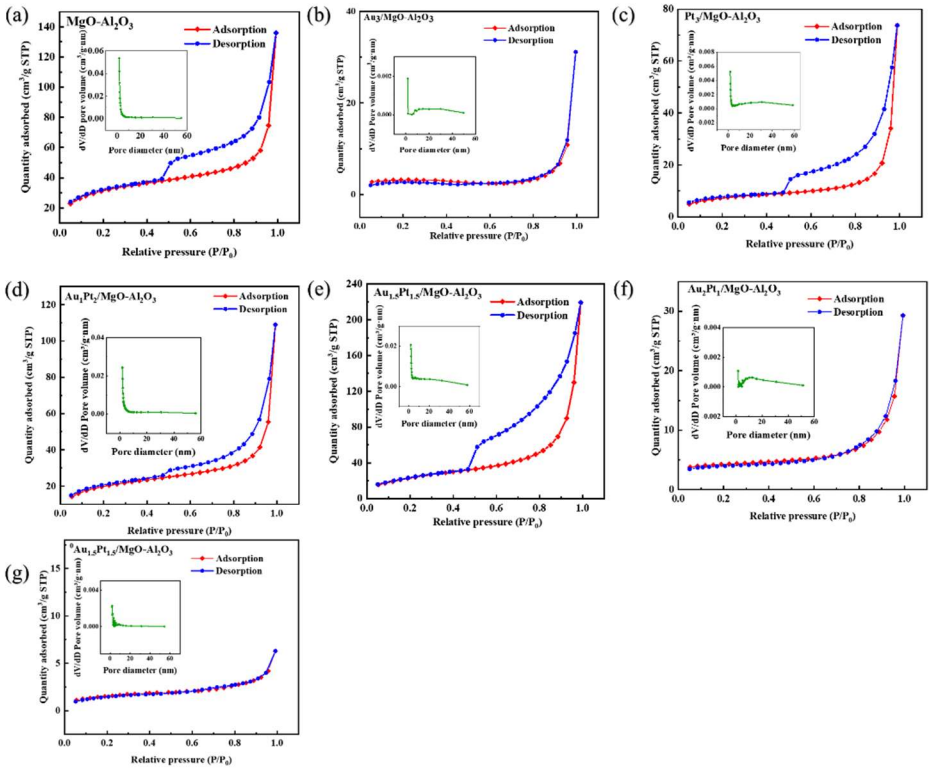


Figure S1. N_2 adsorption–desorption isotherm of (a) MgO-Al_2O_3 (b) Au_3/MgO-Al_2O_3, (c) Pt_3/MgO-Al_2O_3, (d) Au_1Pt_2/MgO-Al_2O_3, (e) Au_2Pt_1/MgO-Al_2O_3 (f) $Au_{1.5}Pt_{1.5}$/ZnO-Al_2O_3 and (g) $^0Au_{1.5}Pt_{1.5}$/MgO-Al_2O_3.

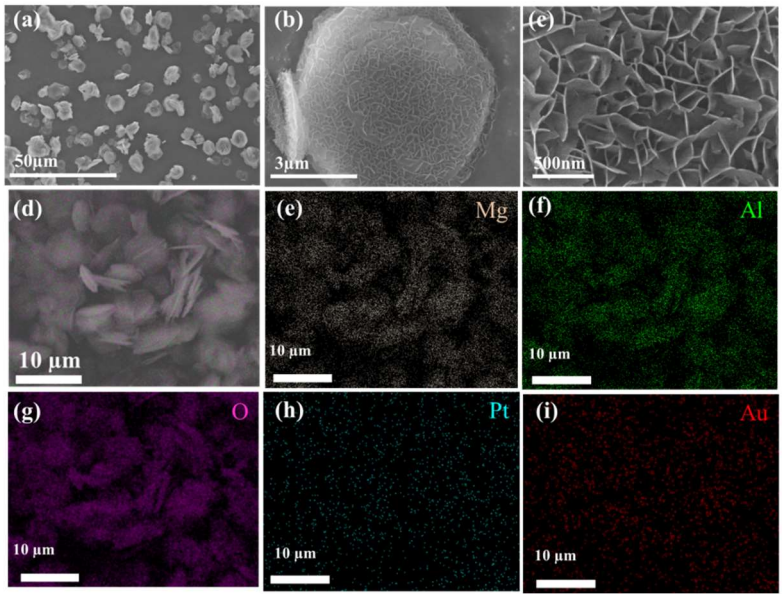


Figure S2. (a-d) SEM image and (e-i) elemental distribution mapping of Mg, Al, O, Pt, and Au in $Au_{1.5}Pt_{1.5}/MgO\text{-}Al_2O_3$ catalyst.

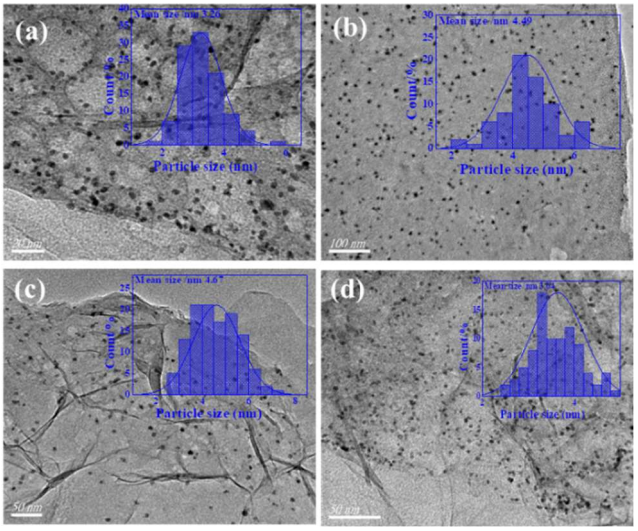


Figure S3. TEM images and size distributions of Au, Pt and AuPt nanoparticles of (a) $Au_3/MgO\text{-}Al_2O_3$; (b) $Pt_3/MgO\text{-}Al_2O_3$; (c) $Au_1Pt_2/MgO\text{-}Al_2O_3$; (d) $Au_2Pt_1/MgO\text{-}Al_2O_3$ catalysts.

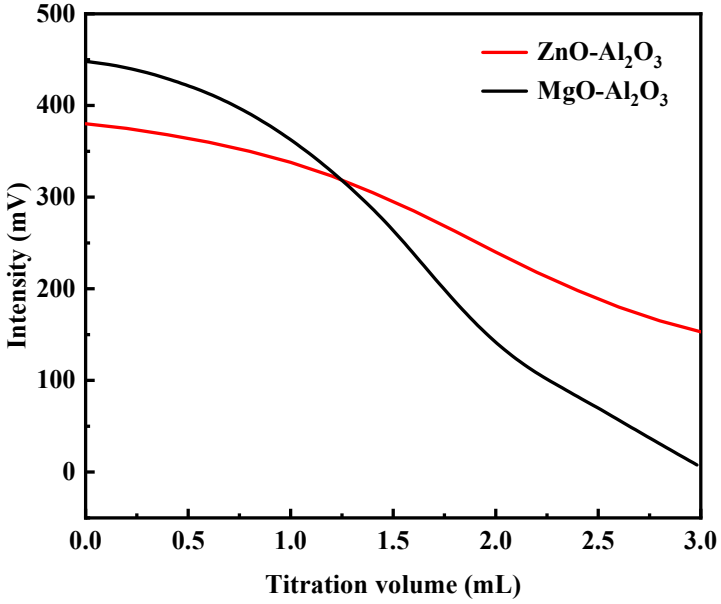


Figure S4. Potentiometric titration curves of catalyst support

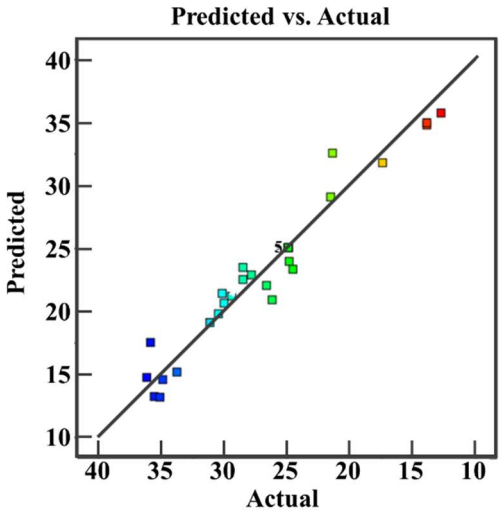


Figure S5. Predicted *vs* experimental values of glyceric acid yield over $Au_{1.5}Pt_{1.5}/MgO\text{-}Al_2O_3$ catalyst.

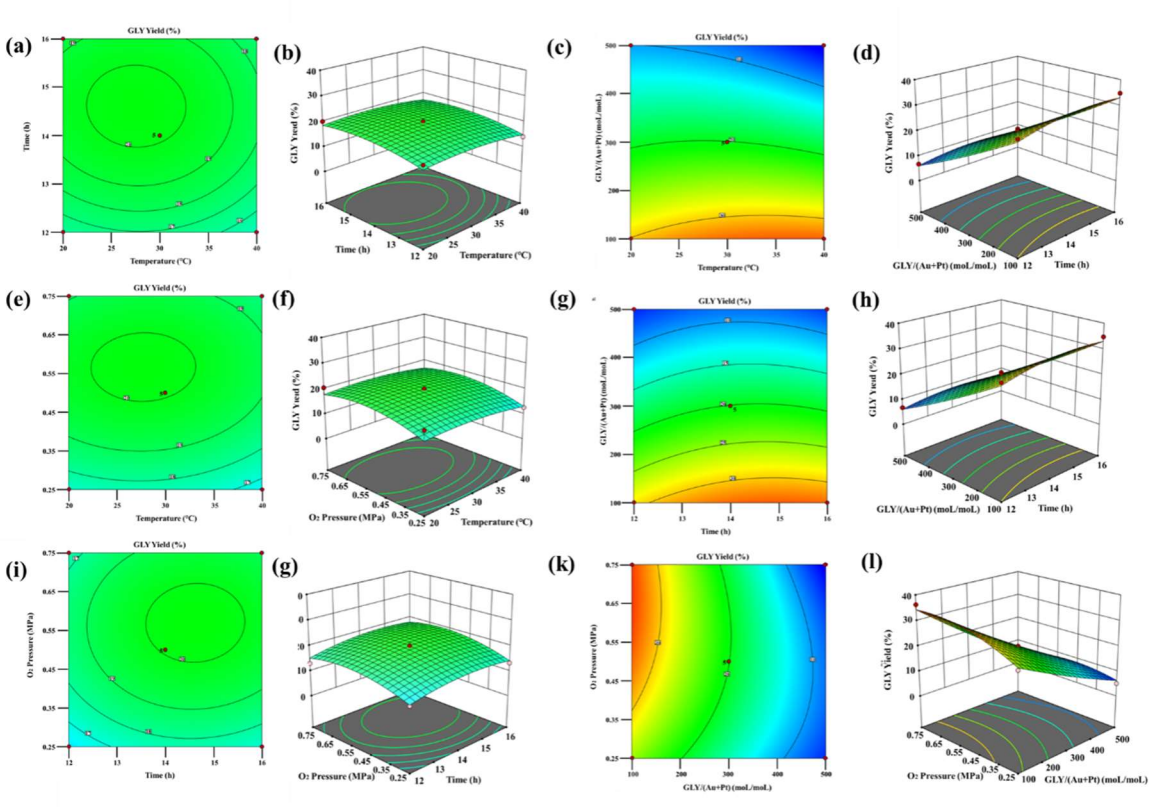


Figure S6. (a, b) The interaction between reaction temperature and time for $Au_{1.5}Pt_{1.5}/MgO\text{-}Al_2O_3$ catalyst. GLY/(Au+Pt) = 300 mol·mol^{-1}, and O_2 pressure = 0.5 Mpa; (c, d) The interaction between reaction temperature and the GLY/(Au+Pt) molar ratio. Reaction time = 14 h, and O_2 pressure = 0.5 MPa; (e, f) The interaction between reaction temperature and O_2 pressure. Reaction time = 14 h, and GLY/(Au+Pt) molar ratio = 300 mol·mol^{-1}; (g, h) The interaction between time and GLY/(Au+Pt) molar ratio. Reaction temperature = 30 °C, and O_2 pressure = 0.5 MPa; (i, j) The interaction between time and pressure. Temperature = 30 °C, GLY/(Au+Pt) molar ratio = 300 mol·mol^{-1}; (k, l) The interaction between the GLY/(Au+Pt) molar ratio and O_2 pressure. Reaction temperature = 30 °C, and reaction time = 14 h.

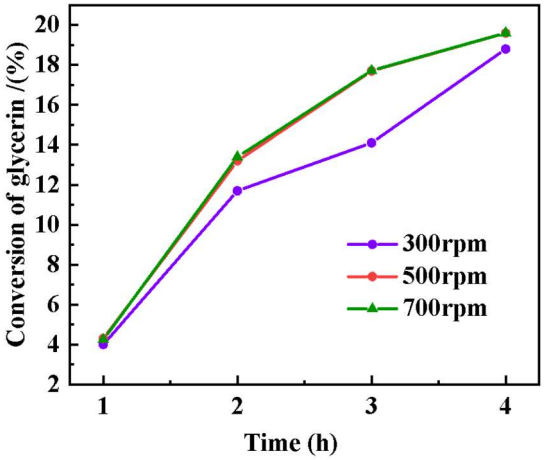


Figure S7. Effect of stirring speed on glycerol conversion. Reaction conditions: 30 mL 0.1M GLY, GLY/(Au+Pt) = 100 mol/mol, P_{O_2} = 0.5 MPa, temperature = 30 °C, and time = 1–4 h.

Table S1. BET surface area, pore volume, and pore size of supported catalysts.

Catalysts	BET surface area ($m^2 \cdot g^{-1}$)	Pore volume ($cm^3 \cdot g^{-1}$)	Pore size (nm)
$MgO\text{-}Al_2O_3$	107.91	0.21	7.60
$Au_3/MgO\text{-}Al_2O_3$	9.89	0.04	18.03
$Pt_3/MgO\text{-}Al_2O_3$	25.60	0.11	24.13
$Au_1Pt_2/MgO\text{-}Al_2O_3$	69.32	0.16	9.49
$Au_{1.5}Pt_{1.5}/MgO\text{-}Al_2O_3$	87.24	0.33	15.26
$Au_2Pt_1/MgO\text{-}Al_2O_3$	13.54	0.04	12.94
$Au_{1.5}Pt_{1.5}/ZnO\text{-}Al_2O_3$	54.52	0.24	17.59
$^0Au_{1.5}Pt_{1.5}/MgO\text{-}Al_2O_3$	5.46	0.01	7.11

Table S2. ANOVA of the fitting model for glyceric acid yield.

Source	Sum of squares	d_f	Mean square	*F*-value	*P*-value Prob > *F*
Model	2017.39	14	144.10	17.45	<0.0001
X_1	4.94	1	4.94	0.5982	0.4521
X_2	17.28	1	17.28	2.09	0.1701
X_3	1808.11	1	1808.11	218.91	<0.0001
X_4	35.36	1	35.36	4.28	0.0575
X_1X_2	0.0225	1	0.0225	0.0027	0.9591
X_1X_3	20.25	1	20.25	2.45	0.1397
X_1X_4	0.04	1	0.04	0.0048	0.9455
X_2X_3	2.56	1	2.56	0.3099	0.5865
X_2X_4	0.1225	1	0.1225	0.0148	0.9048
X_3X_4	29.7	1	29.7	3.6	0.0487
X_1^2	12.12	1	12.12	1.47	0.2459
X_2^2	26.05	1	26.05	3.15	0.0975
X_3^2	3.25	1	3.25	0.394	0.5403
X_4^2	65.56	1	65.56	7.94	0.0139
Lack of Fit	115.63	14	8.26		
Pure Error	0.0000	4	0.0000		
Cor Total	2133.02	28			
C.V.%			16.25		
R^2			0.9548		
Adj R^2			0.9016		

Table S3. Optimum parameters for glycerol oxidation to glyceric acid over $Au_{1.5}Pt_{1.5}/MgO\text{-}Al_2O_3$.

Parameter	Temperature (°C)	Time (h)	GLY/(Au+Pt) (mol/mol)	O_2 Pressure (MPa)	Glyceric acid yield (%)
	X_1	X_2	X_3	X_4	
Predicted	36	15	100	0.68	40.3
Experimental	36	15	100	0.68	41.7
Reaction conditions: 30 mL 0.1M GLY, stirring speed = 500 rpm.					

Table S4. Literature comparison

	Catalyst	Conversion (%)	Selectivity (%)	Reaction conditions	References
[1]	Au-Pt/$M_xO_yC_z$	~100%	57.3%	0.1M GLY, 60℃, 1 MPa O_2, 2 h	[1]
[2]	Au-Pt/HT (Au/Pt ratio 1:5)	64%	69%	0.3 M GLY, 60℃, 0.3 MPa O_2, 4 h	[2]
	Au-Pt/MgO (Au/Pt ratio 1:1)	52%	48%		
	Au-Pt/γ-Al_2O_3 (Au/Pt ratio 1:5)	37%	54%		
[3]	Au-Pt/TiO_2	~10%	11.8%	2 wt% glycerol aqueous solution, 90 ℃, 65 mL/min atmospheric O_2 flow, 2h	[3]
[4]	Au-Pt/T3	92.1%	79.9%	0.3 M GLY, 100℃, 3 atm O_2, 6 h	[4]
[5]	Au-Pt/AC	29.3%	68.4%	5 wt% glycerol aqueous solution, 60 ℃, 15 mL/min atmospheric O_2 flow, LHSV = 0.046.	[5]
[6]	Au_1Pt_3/CeO_2	43.74%	35.91%	0.3 M GLY, 80℃, 0.1 MPa O_2, 2 h	[6]
[7]	AuPt/$LaMnO_3$	~50%	70%	0.3 M GLY, 100℃, 3 bar O_2, 6 h,	[7]
[8]	Au_1Pt_3//TiO_2-001	45%	88%	0.015 M GLY, 80℃, 0.1 MPa O_2, 4 h,	[8]

Table S5. Catalytic performance of $Au_{1.5}Pt_{1.5}/MgO\text{-}Al_2O_3$ catalyst in glycerol oxidation.

Temperature (℃)	Catalyst dosage (g)	O_2 Pressure (MPa)	Glyceric acid yield (%)	Reaction rate (mol·L^{-1}·h^{-1})
20	0.2018	0.50	4.3	0.0022
30	0.2018	0.50	7.8	0.0039
40	0.2018	0.50	9.3	0.0046
50	0.2018	0.50	16.6	0.0083
30	0.0202	0.50	2.9	0.0015
30	0.0404	0.50	3.2	0.0016
30	0.0807	0.50	4.6	0.0023
30	0.2018	0.25	5.7	0.0029
30	0.2018	0.75	8.0	0.0040
30	0.2018	1.00	8.4	0.0042

Reaction conditions: 30 mL 0.1 M glycerol solution, reaction time = 2 h, stirring speed 500 rpm.

Table S6. Levels of studied factors use in the optimization of glyceric acid yield in BBD experimental design.

Symbol	Variables	Coded levels		
		−1	**0**	**+1**
X_1	Reaction temperature	20	30	40
X_2	Reaction time	12	14	16
X_3	GLY/(Au+Pt) molar ratio	100	300	500
X_4	O_2 Pressure	0.25	0.5	0.75

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