Electronic Supplementary Information

Layered double hydroxide supported gold nanoclusters by glutathione-capped Au nanoclusters precursor method for highly efficient aerobic oxidation of alcohols

Lun Li, Liguang Dou and Hui Zhang*

State Key Laboratory of Chemical Resource Engineering, Beijing University of Chemical Technology, Beijing 100029, P. R. China.

* *E-mail: huizhang67@gst21.com;*

Fax: +8610-6442 5385;

Tel: +8610-6442 5872

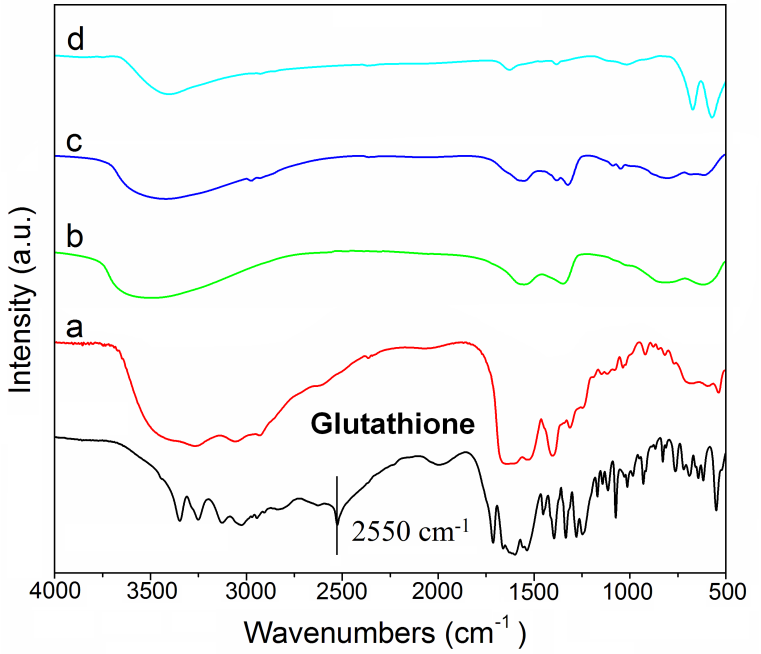

Fig. S1 FTIR spectra of glutathione, GS-AuNCs (a), AuNCs/Mg_3Al-LDH-0.23 (b), AuNCs/Ni_3Al-LDH-0.22 (c), AuNCs/Co_3Al-LDH-0.20 (d).

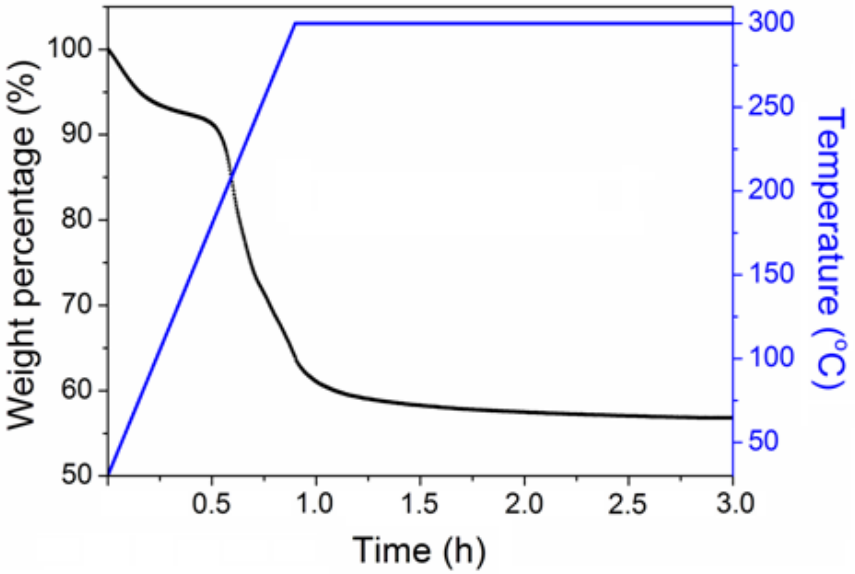

Fig. S2 TG analysis of GS-AuNCs.

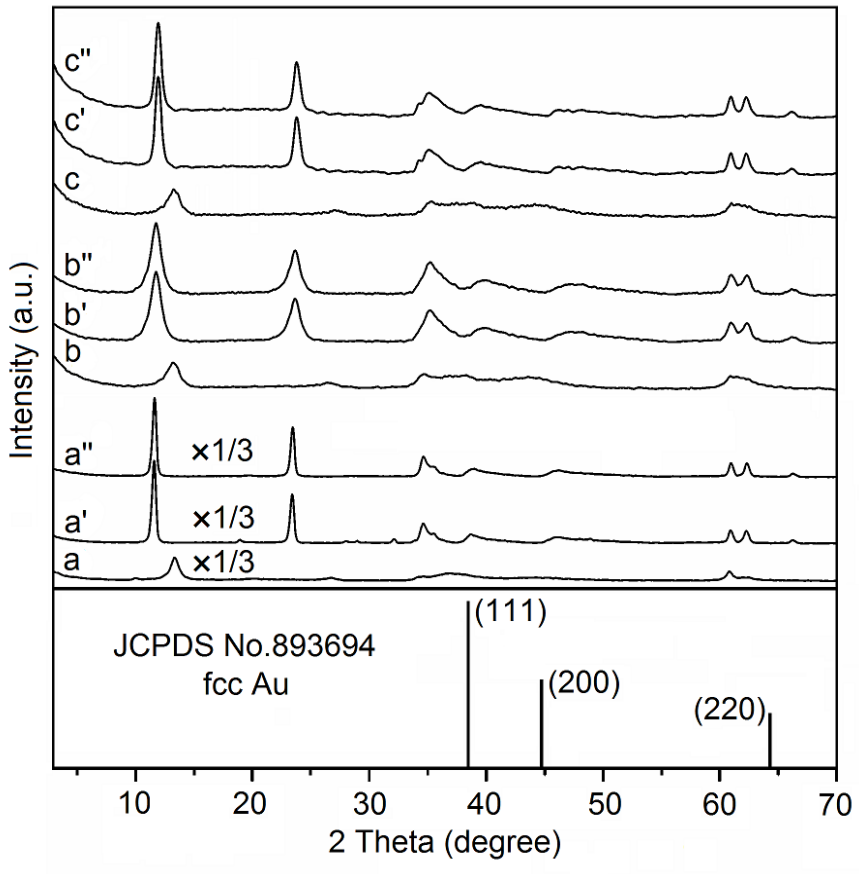

Fig. S3 XRD patterns of AuNCs/Mg_3Al-LDH-0.59 (a), GS-AuNCs/Mg_3Al-LDH-10 (a') Mg_3Al-LDH (a''), AuNCs/Ni_3Al-LDH-0.22 (b) GS-AuNCs/Ni_3Al-LDH-4 (b'), Ni_3Al-LDH (b''), AuNCs/Co_3Al-LDH-0.20 (c), GS-AuNCs/Co_3Al-LDH-4 (c'), Co_3Al-LDH (c'').

Table S1 XRD parameters of the LDH supported Au nanoclusters catalysts.

Samples	d_{003}/nm	d_{110}/nm	c/nm [a]	a/nm [a]	M^{2+}/Al^{3+} [b]
Mg_3Al-LDH	0.762	0.1523	2.286	0.3046	2.98
GS-AuNCs/Mg_3Al-LDH-10	0.762	0.1523	2.286	0.3046	
AuNCs/Mg_3Al-LDH-0.59	0.663	0.1525	1.989	0.3050	
Ni_3Al-LDH	0.758	0.1509	2.274	0.3018	2.95
GS-AuNCs/Ni_3Al-LDH-4	0.756	0.1509	2.268	0.3018	
AuNCs/Ni_3Al-LDH-0.22	0.668	0.1506	2.004	0.3012	
Co3Al-LDH	0.769	0.1538	2.307	0.3076	2.96
GS-AuNCs/Co_3Al-LDH-4	0.770	0.1538	2.310	0.3076	
AuNCs/Co_3Al-LDH-0.20	0.668	0.1536	2.004	0.3072	

[a] Based on hexagonal crystal system, $a = 2d_{110}$, $c = 3d_{003}$.

[b] Based on ICP data.

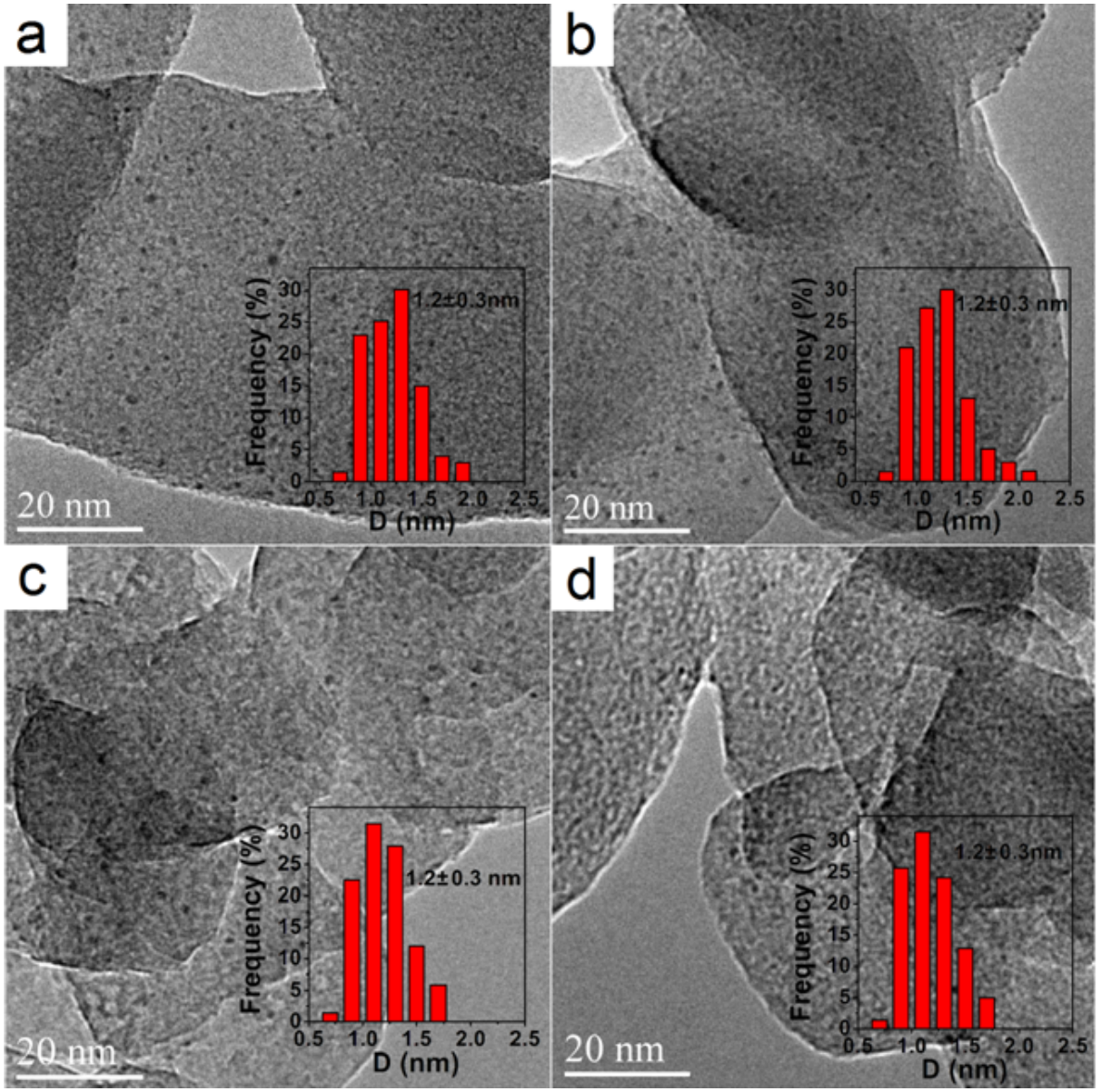

Fig. S4 HRTEM images of the precursors GS-Au/Mg_3Al-LDH-16 (a), GS-Au/Mg_3Al-LDH-10 (b), GS-Au/Mg_3Al-LDH-4 (c), and GS-Au/Mg_3Al-LDH-2 (d).

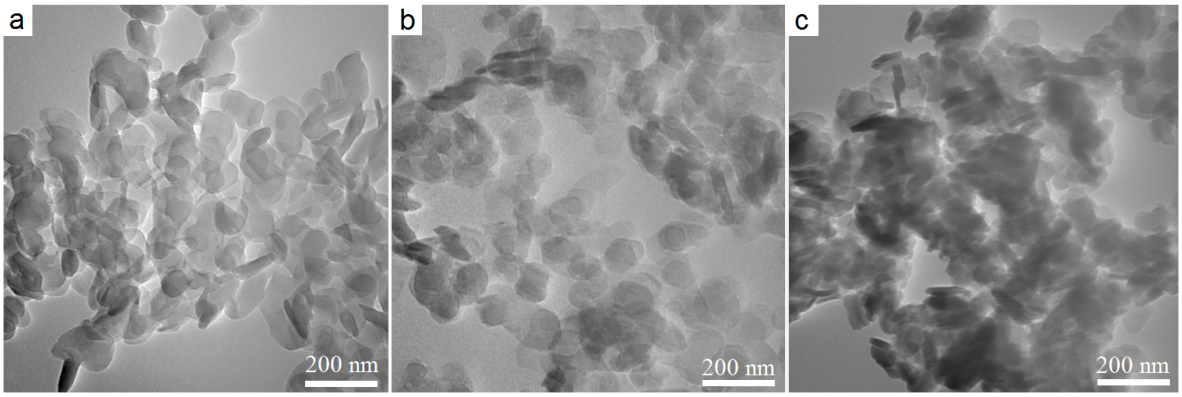

Fig. S5 TEM images of the supports Mg_3Al-LDH (a), Ni_3Al-LDH (b) and Co_3Al-LDH (c).

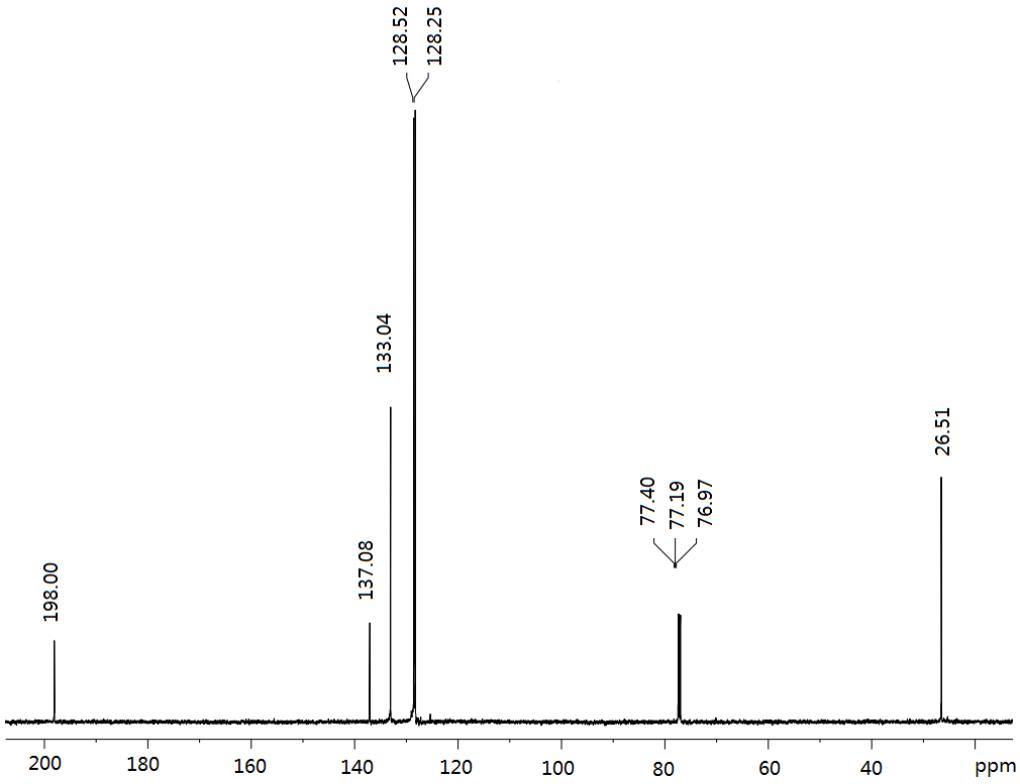

Fig. S6 ^{13}C NMR spectrum of the oxidation product of 1-pheylethanol (reaction conditions: 1-phenylethanol (100 mmol), catalyst (AuNCs/Mg_3Al-LDH-0.23, Au: 4.0×10^{-4} mol%), O_2 (20 mL/min), 160 °C, 24 h)

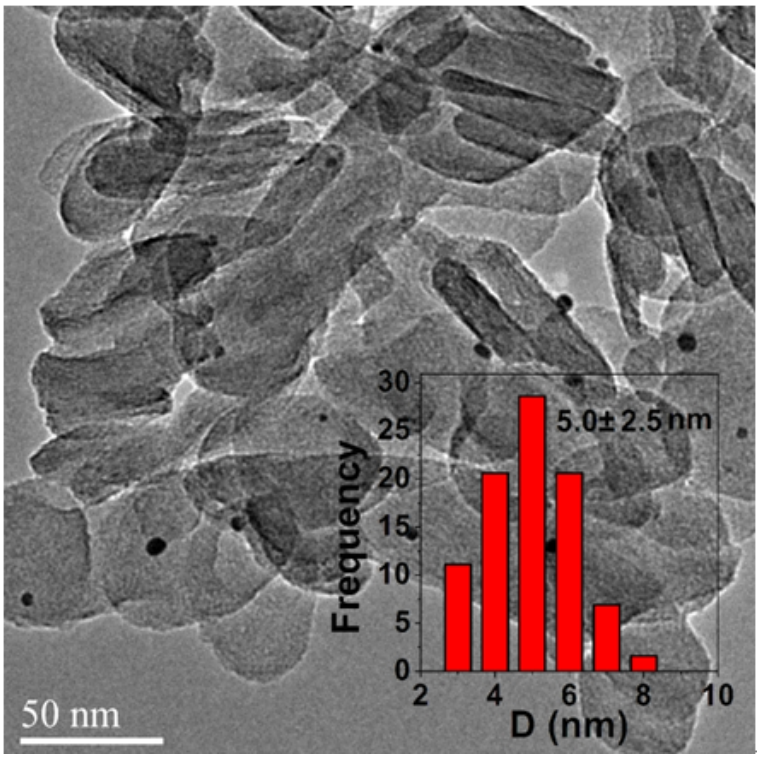

Fig. S7 TEM image of Au/Mg_3Al-LDH(DP).

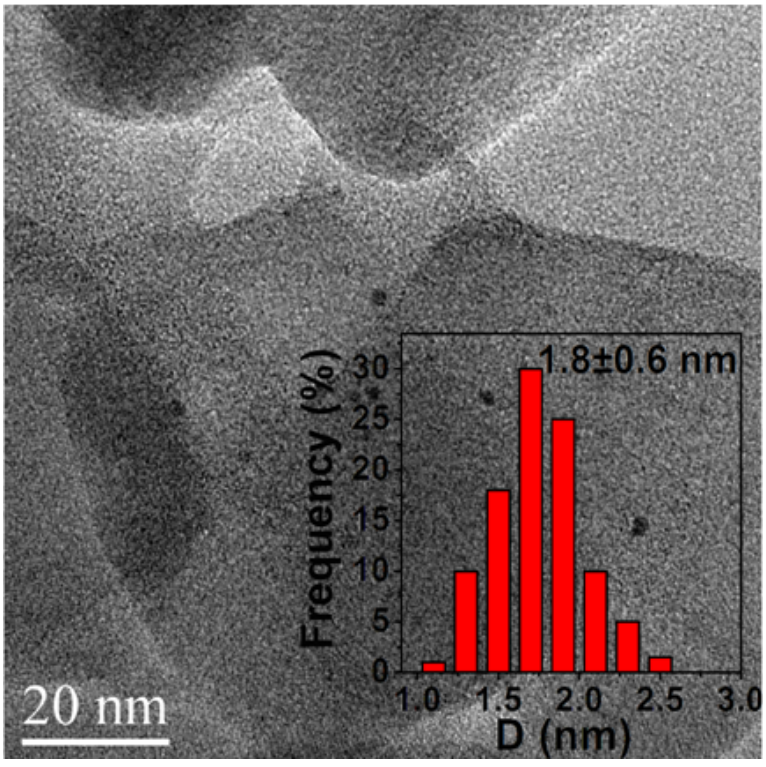

Fig. S8 TEM image of AuNCs/Mg_3Al-LDH-0.23 recovered from the fifth run.

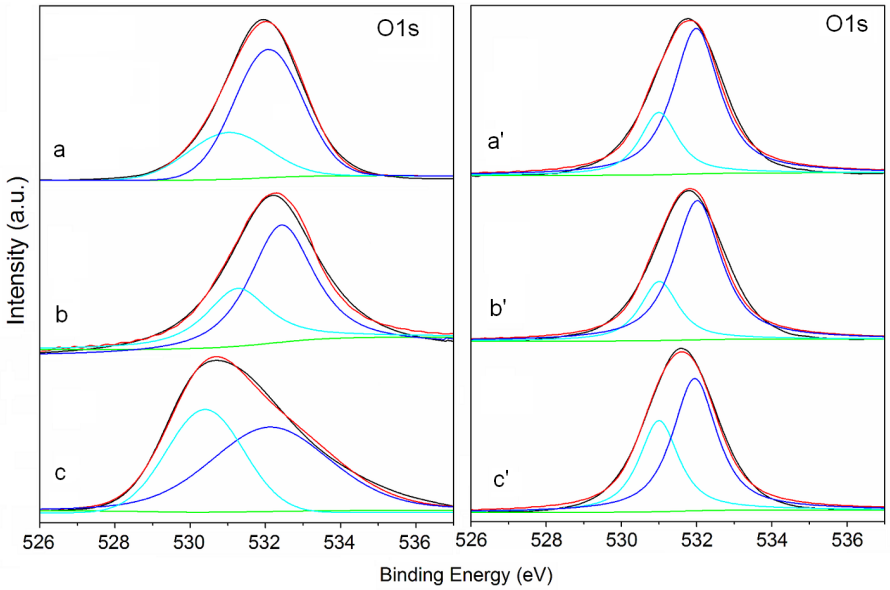

Fig. S9 O1s XPS spectra of AuNCs/Mg_3Al-LDH-0.59 (a), Mg_3Al-LDH-10 (a') Mg_3Al-LDH, AuNCs/Ni_3Al-LDH-0.22 (b) Ni_3Al-LDH (b'), AuNCs/Co_3Al-LDH-0.20 (c), Co_3Al-LDH (c').

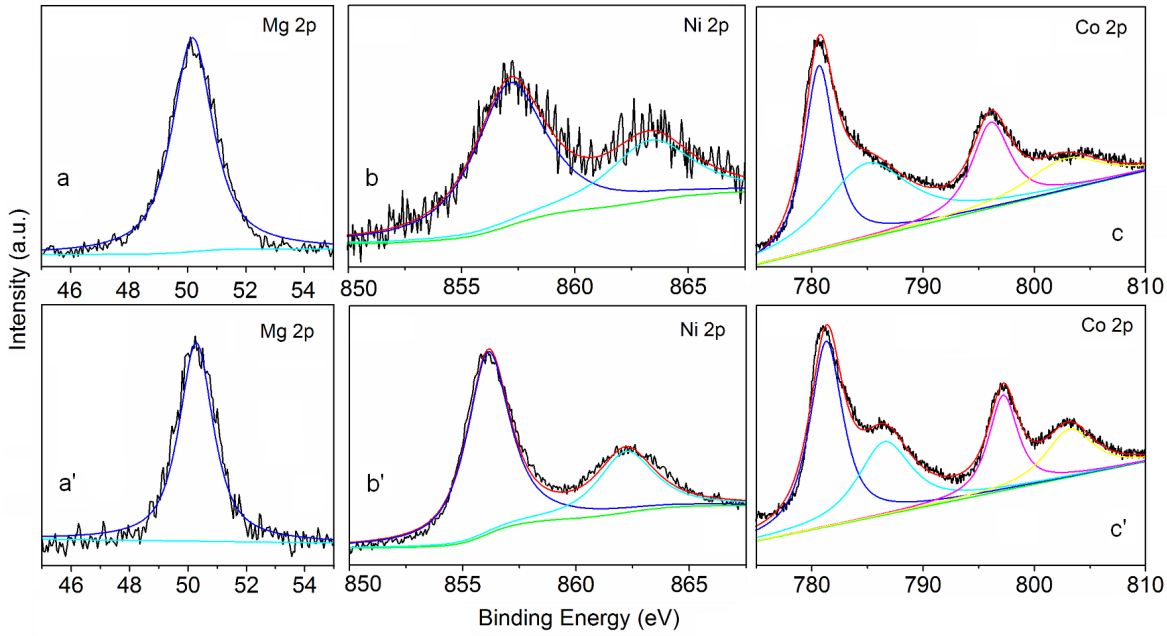

Fig. S10 Mg, Ni, Co 2p XPS spectra of AuNCs/Mg_3Al-LDH-0.59 (a), Mg_3Al-LDH-10 (a') Mg_3Al-LDH, AuNCs/Ni_3Al-LDH-0.22 (b) Ni_3Al-LDH (b'), AuNCs/Co_3Al-LDH-0.20 (c), Co_3Al-LDH (c').

Table S2 XPS analysis and isoelectronic point determination data of the catalysts compared with the supports

Sample	M $2p_{3/2}$ (M = Mg, Ni, Co) (eV)	O1s (eV) (-OH)	O1s (eV) (O^{2-})	pI [a]
AuNCs/Mg_3Al-LDH-0.23	50.2	532.0 (70%)	531.0 (30%)	10.3
Mg_3Al-LDH	50.2	532.0 (74%)	531.0 (26%)	11.0
AuNCs/Ni_3Al-LDH-0.22	856.9	532.4 (68%)	531.2 (32%)	10.0
Ni_3Al-LDH	855.9	532.0 (73%)	531.0 (27%)	10.4
AuNCs/Co_3Al-LDH-0.20	780.2	532.0 (53%)	530.4 (47%)	9.5
Co_3Al-LDH	780.8	532.0 (65%)	531.0 (35%)	10.2

[a] Upon the zeta potential determination on a Malvern Zetasizer Nano ZS instrument equipped with a multipurpose autotitrator (MPT-2). The sample suspension was prepared by dispersing of 1 mg nanoparticles in 1 ml of ultrapure water and subsequently the suspension was ultrasonically agitated for 10 min. The zeta potential depended on pH, as titration solutions 0.25 M HCl and 0.25 M NaOH were used.