Supporting information for

Ultralight and Spongy La-Mn-based Perovskite Catalysts Modified by Alkali Metals and Ce: Facile Synthesis and Excellent Catalytic Performance for Soot Combustion

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Experimental details

The reaction rate (v and v^*), active redox sites (O* amount), density of active redox sites (O* density) and TOF values of catalysts were determined by isothermal reaction for soot combustion, and their values are calculated by the following equations[1]:

$$\mathrm{TOF}\ (\mathrm{s}^{-1}) = \frac{v}{\mathrm{O}^*\ \mathrm{amount}}$$

$$v\ (\mathrm{mol\ s}^{-1}\ \mathrm{g}^{-1}) = -\frac{dn}{mdt} = \frac{x_{CO_2} \times n_{CO_2}}{m}$$

$$v^*\ (\mathrm{mol\ s}^{-1}\ \mathrm{m}^{-2}) = \frac{v}{\mathrm{S}} = \frac{x_{CO_2} \times n_{CO_2}}{m\mathrm{S}}$$

where x_{CO_2} is the mole fraction of CO_2; n_{CO_2} is the molar amount of CO_2 (mol); m is the mass of the catalyst (g); S is the BET specific surface area of catalyst (m^2/g)

$$\mathrm{O}^*\ \mathrm{amount}\ (\mathrm{mol\ g}^{-1}) = \frac{2P_0V \times A \times 10^{-6}}{RTm}$$

$$\mathrm{O}^*\ \mathrm{density}\ (\mathrm{nm}^{-2}) = \frac{\mathrm{O}^*\ \mathrm{amount}}{\mathrm{S} \times 10^{18}} \times 6.02 \times 10^{23}$$

where P_0 is the atmospheric pressure (Pa); A is the integrated area of CO_2 concentration as a function of time (s); V is the volumetric flow rate of gases (m^3/s); m is the mass of the catalyst (g); R is the gas constant (8.314 J/mol·K); T is room temperature (K); S is the BET specific surface area (m^2/g).

Table S1 Recipes for the synthesis of as-prepared La-Mn-based perovskite catalysts

Catalysts	$La(NO_3)_3\cdot 6H_2O$ /g	$Ce(NO_3)_3\cdot 6H_2O$ /g	Alkali metal nitrates	$Mn(NO_3)_2$ /g	Glucose /g	H_2O/ mL
$LaMnO_3$	4.33	-	-	3.56	3.92	20
$La_{0.98}Ce_{0.01}Cs_{0.01}MnO_3$	4.24	0.0434	0.0195 g $CsNO_3$	3.56	3.92	20
$La_{0.96}Ce_{0.02}Cs_{0.02}MnO_3$	4.16	0.0868	0.0390 g $CsNO_3$	3.56	3.92	20
$La_{0.94}Ce_{0.03}Cs_{0.03}MnO_3$	4.07	0.1302	0.0585 g $CsNO_3$	3.56	3.92	20
$La_{0.9}Ce_{0.05}Cs_{0.05}MnO_3$	3.90	0.217	0.0975 g $CsNO_3$	3.56	3.92	20
$La_{0.85}Ce_{0.075}Cs_{0.075}MnO_3$	3.68	0.325	0.146 g $CsNO_3$	3.56	3.92	20
$La_{0.8}Ce_{0.1}Cs_{0.1}MnO_3$	3.46	0.434	0.195 g $CsNO_3$	3.56	3.92	20
$La_{0.6}Ce_{0.2}Cs_{0.2}MnO_3$	2.59	0.868	0.390 g $CsNO_3$	3.56	3.92	20
$La_{0.8}Ce_{0.2}MnO_3$	3.46	0.868	-	3.56	3.92	20
$La_{0.8}Cs_{0.2}MnO_3$	3.46	-	0.390 g $CsNO_3$	3.56	3.92	20
$La_{0.8}Ce_{0.1}Li_{0.1}MnO_3$	3.46	0.434	0.068 g $LiNO_3$	3.56	3.92	20
$La_{0.8}Ce_{0.1}Na_{0.1}MnO_3$	3.46	0.434	0.084 g $NaNO_3$	3.56	3.92	20
$La_{0.8}Ce_{0.1}K_{0.1}MnO_3$	3.46	0.434	0.101 g KNO_3	3.56	3.92	20
$La_{0.8}Ce_{0.1}Rb_{0.1}MnO_3$	3.46	0.434	0.147 g $RbNO_3$	3.56	3.92	20

Table S2. Comparation for catalytic performance of as-prepared and reported catalysts for soot combustion

Catalyst	Soot/catalyst weight ratio	Contact mode	Reaction conditions	Heating rate (°C/min)	T_{10} (°C)	T_{50}/T_m (°C)	T_{90} (°C)	Sm CO2(%)	Ref
3DOM La_2NiCoO_6	1/10	Loose	Flow 50 mL/min, 5%O_2+0.2%NO+ 5%H_2O+Ar balance	2	288	362	412	98.6	2
$La_{(1-x)}Ag_xCoO_3$ (x=2.5%)	1/10	Loose	Flow 300 mL/min, 10%O_2+500 ppm NO+N_2 balance	4	302	358	448	-	3
3DOM $La_{0.95}K_{0.05}NiO_3$	1/10	Loose	Flow 50 mL/min, 5%O_2+2000 ppm NO+N_2 balance	2	289	338	372	98.7	4
K–Mn/3DOM $La_{0.8}Ce_{0.2}FeO_3$	1/9	Loose	Flow 50 mL/min, 5%O_2+500 ppm NO+N_2 balance	2	316	377	430	96.5	5
$LaCo_{0.94}Pt_{0.06}O_3$	1/10	Loose	Flow 100 mL/min, 2000 ppm NO/air	10	344	403	435	-	6
3DOM $La_{0.5}Sr_{0.5}MnO_3$	1/9	Loose	Flow 100mL/min, 20% O_2+500ppm NO + N_2 balance	5	320	385	428	-	7
$La_{0.7}K_{0.3}FeO_{3-\delta}$ nanotubes	1/9	Loose	Flow 100 mL/min, 20%O_2+500 ppm NO	2	355	393	429	94.0	8
Ce_1MnO_x	1/10	Loose	Flow 50 mL/min, 10%O_2+2000 ppm NO+Ar balance	2	268	332	369	99.4	9
K-OMS-2/3DOMM $Ti_{0.7}Si_{0.3}O_2$	1/10	Loose	Flow 50 mL/min, 10% O_2+0.2% NO+Ar balance	2	288	333	364	97.8	10
MnO_x–CeO_2	1/9	Loose	Flow 100 mL/min, 10%O_2+N_2 balance	3	314	346	383	-	11
3DOM $Au_2Pt_2/Ce_{0.8}Zr_{0.2}O_2$	1/10	Loose	Flow 50mL/min, 10%O_2+0.2%NO+balance	2	236	345	397	99.5	12
3 wt.% $Pt/Mn_{0.5}Ce_{0.5}O_{2-\delta}$	1/10	Loose	Flow 50 mL/min, 10% O_2+0.2% NO+Ar balance	2	290	342	373	96.7	13
Pt-CoO_x/3DOM-Al_2O_3	1/10	Loose	Flow 50 mL/min, 5%O_2+0.2%NO+Ar balance	2	281	368	416	99.1	14
PdAu@CeO_2/CZ	1/10	Loose	Flow 50mL/min, 5%O_2+0.2%H_2O+Ar balance	2	276	363	404	99.6	15
$La_{0.8}Ce_{0.1}Cs_{0.1}MnO_3$	1/10	Loose	Flow 50 mL/min, 10%O_2+2000 ppm NO +Ar balance	2	268	315	350	98.5	This work
$La_{0.8}Ce_{0.1}Cs_{0.1}MnO_3$	1/10	Loose	Flow 50 mL/min, 10%O_2 +2000 ppm NO ++10%H_2O+Ar balance	2	265	304	329	96.7	This work

Table S3 The stability and sulfur water resistant of $La_{0.8}Ce_{0.1}Cs_{0.1}MnO_3$ catalysts for soot combustion

Catalysts	T_{10}/°C	T_{50}/°C	T_{90}/°C	Sco_2^m/%
$La_{0.8}Ce_{0.1}Cs_{0.1}CoO_3$-Cycle 1	268	314	350	98.5
$La_{0.8}Ce_{0.1}Cs_{0.1}CoO_3$-Cycle 2	272	319	350	98.3
$La_{0.8}Ce_{0.1}Cs_{0.1}CoO_3$-Cycle 3	269	318	351	98
$La_{0.8}Ce_{0.1}Cs_{0.1}CoO_3$-Cycle 4	280	329	361	97.5
$La_{0.8}Ce_{0.1}Cs_{0.1}CoO_3$-Cycle 5	279	329	361	97.8
10%H_2O+0 ppm SO_2	265	304	329	96.7
10%H_2O+100 ppm SO_2	296	332	442	93.8
10%H_2O+300 ppm SO_2	387	459	500	82.8

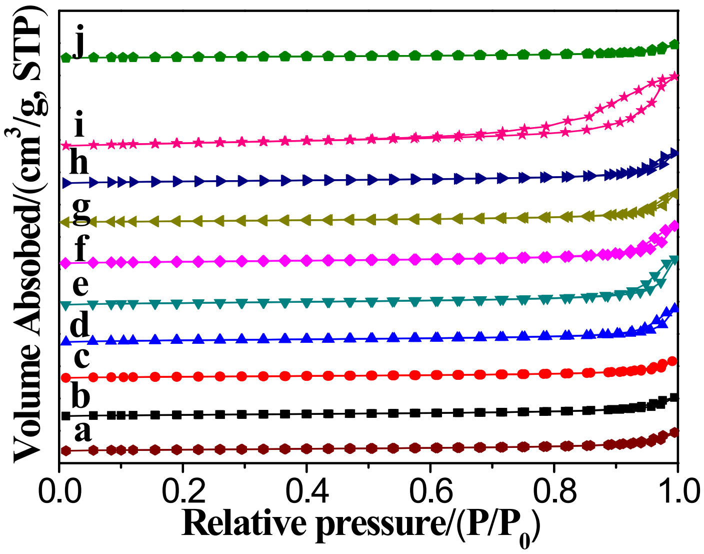


Figure S1. Nitrogen adsorption-desorption isotherms of La-Mn-based perovskite catalysts with different A sites (a: $LaMnO_3$; b: $La_{0.98}Ce_{0.01}Cs_{0.01}MnO_3$; c: $La_{0.96}Ce_{0.02}Cs_{0.02}MnO_3$; d: $La_{0.94}Ce_{0.03}Cs_{0.03}MnO_3$; e: $La_{0.9}Ce_{0.05}Cs_{0.05}MnO_3$; f: $La_{0.85}Ce_{0.075}Cs_{0.075}MnO_3$; g: $La_{0.8}Ce_{0.1}Cs_{0.1}MnO_3$; h: $La_{0.6}Ce_{0.2}Cs_{0.2}MnO_3$; i: $La_{0.8}Ce_{0.2}MnO_3$; j: $La_{0.8}Cs_{0.2}MnO_3$)

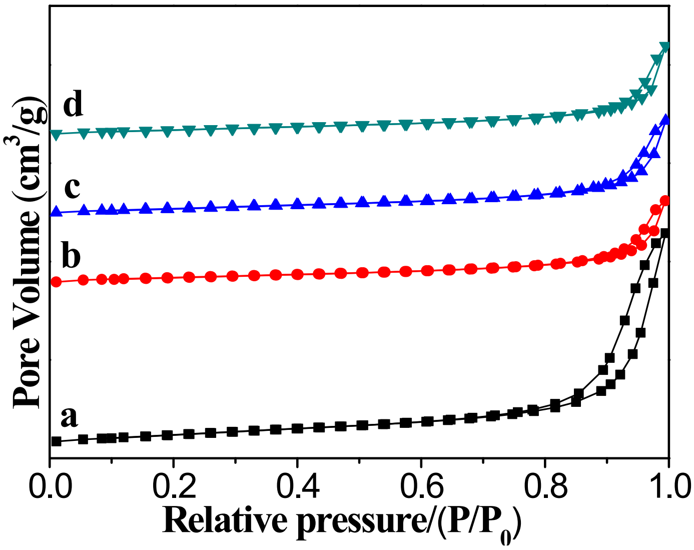


Figure S2. Nitrogen adsorption-desorption isotherms of $La_{0.8}Ce_{0.1}A_{0.1}MnO_3$ catalyst
(a: $La_{0.8}Ce_{0.1}Li_{0.1}MnO_3$; b: $La_{0.8}Ce_{0.1}Na_{0.1}MnO_3$; c: $La_{0.8}Ce_{0.1}K_{0.1}MnO_3$; d:$La_{0.8}Ce_{0.1}Rb_{0.1}MnO_3$)

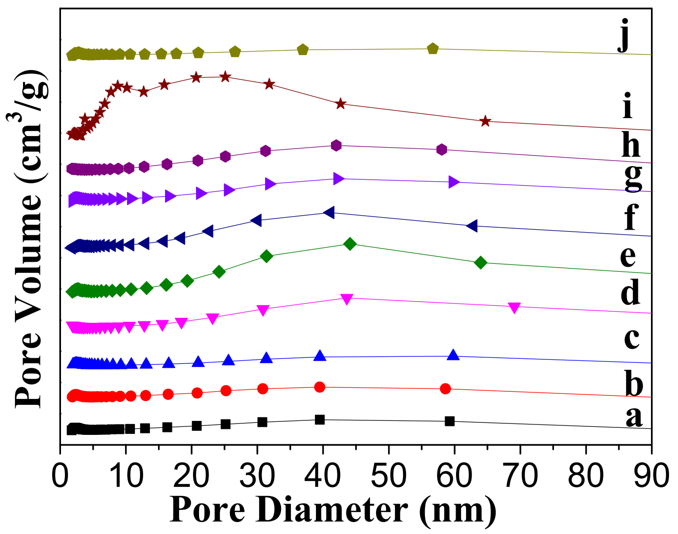


Figure S3. Pore distribution of La-Mn-based perovskite catalysts with different A sites (a: $LaMnO_3$; b: $La_{0.98}Ce_{0.01}Cs_{0.01}MnO_3$; c: $La_{0.96}Ce_{0.02}Cs_{0.02}MnO_3$; d: $La_{0.94}Ce_{0.03}Cs_{0.03}MnO_3$; e: $La_{0.9}Ce_{0.05}Cs_{0.05}MnO_3$; f: $La_{0.85}Ce_{0.075}Cs_{0.075}MnO_3$; g: $La_{0.8}Ce_{0.1}Cs_{0.1}MnO_3$; h: $La_{0.6}Ce_{0.2}Cs_{0.2}MnO_3$; i: $La_{0.8}Ce_{0.2}MnO_3$; j: $La_{0.8}Cs_{0.2}MnO_3$)

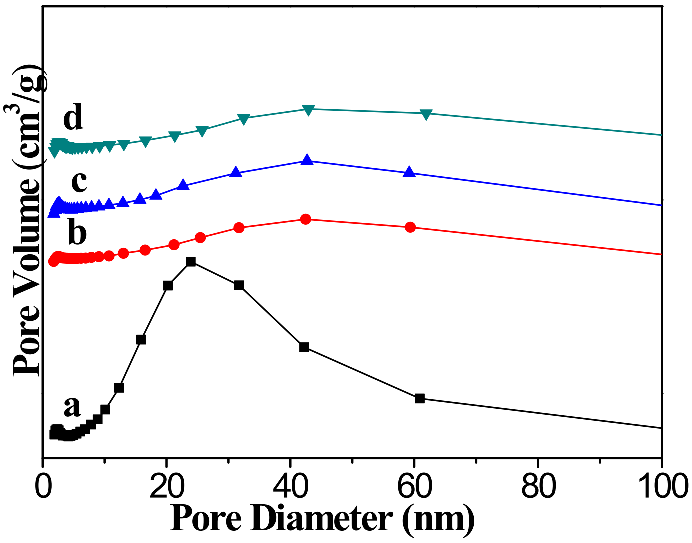


Figure S4. Pore distribution of $La_{0.8}Ce_{0.1}A_{0.1}MnO_3$ catalysts

(a: $La_{0.8}Ce_{0.1}Li_{0.1}MnO_3$; b: $La_{0.8}Ce_{0.1}Na_{0.1}MnO_3$; c: $La_{0.8}Ce_{0.1}K_{0.1}MnO_3$; d: $La_{0.8}Ce_{0.1}Rb_{0.1}MnO_3$)

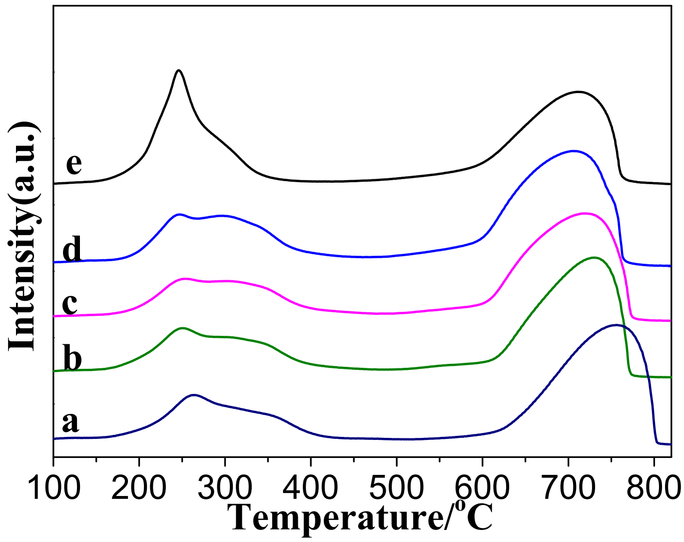


Figure S5. H_2-TPR curves of La-Mn-based perovskite catalysts with different A sites
a: $LaMnO_3$; b: $La_{0.98}Ce_{0.01}Cs_{0.01}MnO_3$; c: $La_{0.96}Ce_{0.02}Cs_{0.02}MnO_3$; d: $La_{0.94}Ce_{0.03}Cs_{0.03}MnO_3$; e: $La_{0.85}Ce_{0.075}Cs_{0.075}MnO_3$)

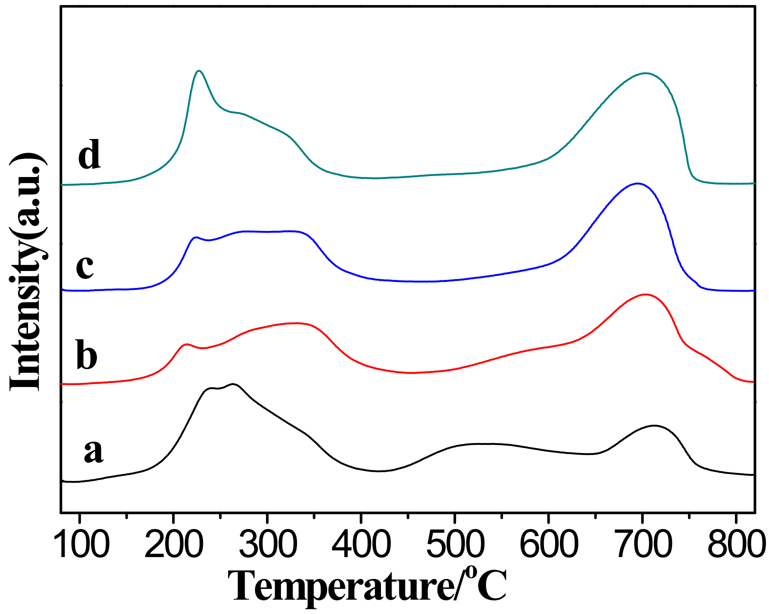
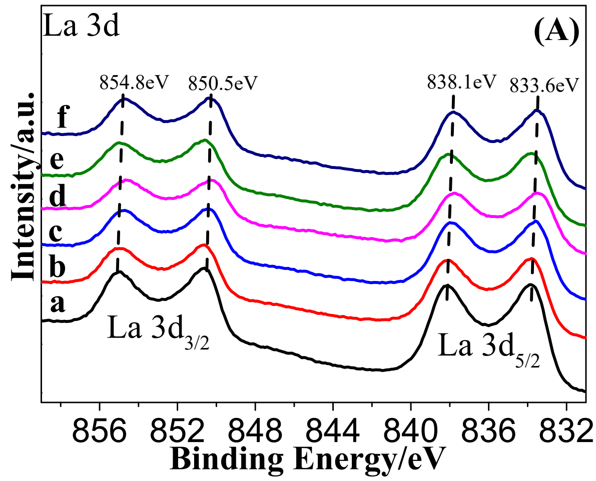


Figure S6. H_2-TPR curves of $La_{0.8}Ce_{0.1}A_{0.1}MnO_3$ catalysts
(a: $La_{0.8}Ce_{0.1}Li_{0.1}MnO_3$; b: $La_{0.8}Ce_{0.1}Na_{0.1}MnO_3$; c: $La_{0.8}Ce_{0.1}K_{0.1}MnO_3$; d: $La_{0.8}Ce_{0.1}Rb_{0.1}MnO_3$)



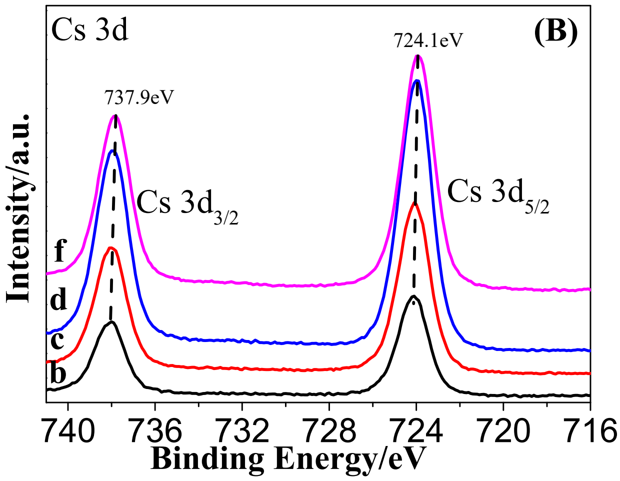


Figure S7. XPS spectra of La 3d (A) and Cs 3d (B) for as-prepared catalysts

(a: $LaMnO_3$; b: $La_{0.9}Ce_{0.05}Cs_{0.05}MnO_3$; c: $La_{0.8}Ce_{0.1}Cs_{0.1}MnO_3$; d: $La_{0.6}Ce_{0.2}Cs_{0.2}MnO_3$; e: $La_{0.8}Ce_{0.2}MnO_3$; f: $La_{0.8}Cs_{0.2}MnO_3$)

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