Supporting Information for

The porous hollow CoInOx nanocube as a highly efficient catalyst for the catalytic combustion of toluene

Fang Dong[a], Weiliang Han[a], Haijun Zhao[a], Guodong Zhang[a], Zhicheng Tang[a] *

a State Key Laboratory for Oxo Synthesis and Selective Oxidation, and National Engineering Research Center for Fine Petrochemical Intermediates, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou 730000, China

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**Corresponding author: State Key Laboratory for Oxo Synthesis and Selective Oxidation, and National Engineering Research Center for Fine Petrochemical Intermediates, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou 730000, PR China.*

E-mail address: tangzhicheng@licp.cas.cn

S1 Experimental details

S1.1 The calculation of Ea (Activation energy):

Reaction rate (r) and activation energy (Ea) is evaluated according to the equation (3), (4), (5) and (6):

$$r = \frac{F0}{mcat} \times \{ - \ln (1 - x)\} \quad (3)$$

$$r = kC0 \quad (4)$$

$$k = Aexp(\frac{- Ea}{RT}) \quad (5)$$

$$lnr = - \frac{Ea}{RT} + B \quad (6)$$

r, A and Ea is the reaction rate (mol s^{-1}), pre-exponential factor, and apparent activation energy Ea (kJ mol^{-1}), respectively. B is kinetic constant.

S1.2 Stability test

The stability was tested at the different reaction temperature with 3000 ppm toluene for 64 h (160 °C for 32 h and 200 °C for 32 h). Before this test, the catalyst had been treated at 300 °C for 4 h under reaction conditions (3000 ppm Toluene, 400mg catalysts, 30 000 ml g^{-1} h^{-1}).

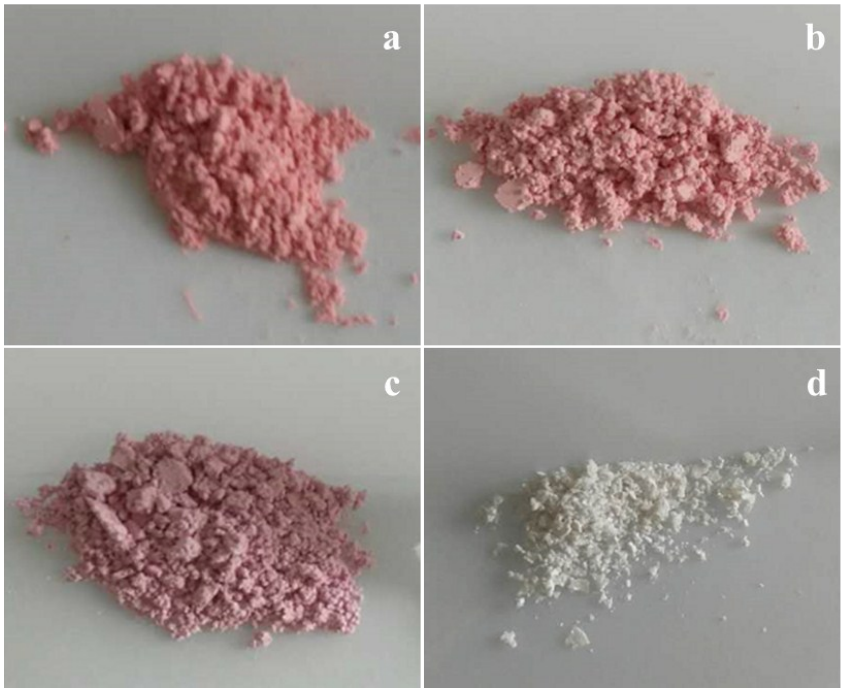

Figure S1 The photos of (a) C-CoInOOx precursor, (b) HC-CoInOx precursor, (c) HC-CoOx precursor and (d) InOx precursor

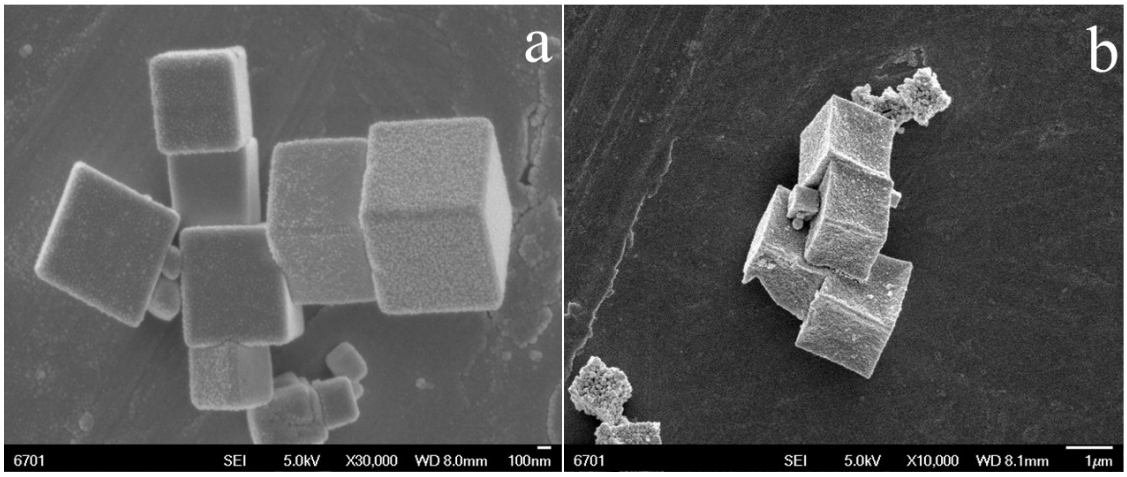

Figure S2. SEM images of a) CoIn-PBA prefersor, and b) the C-CoInOx sample (fired at 450 °C)

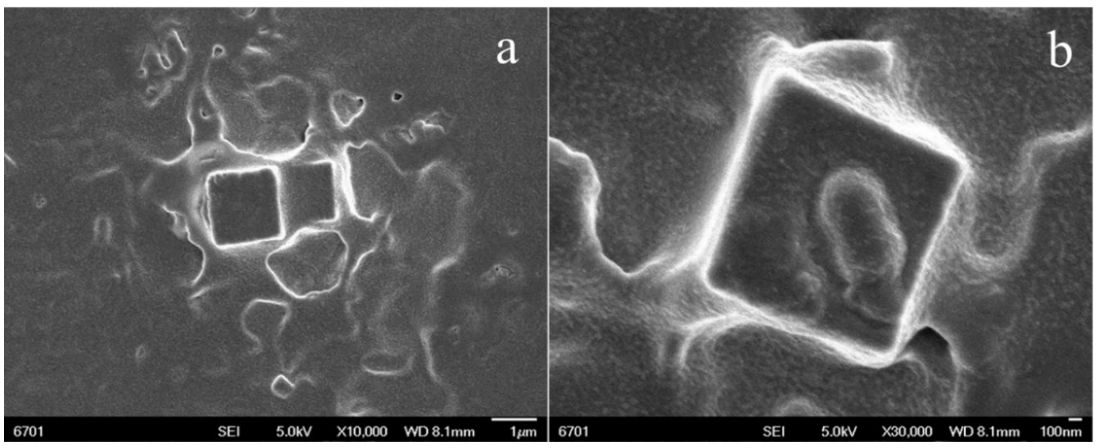

Figure S3. SEM images of a) SiO_2@CoIn-PBA@SiO_2 (unfired), b) SiO_2@CoInOx@SiO_2 (fired at 450 °C)

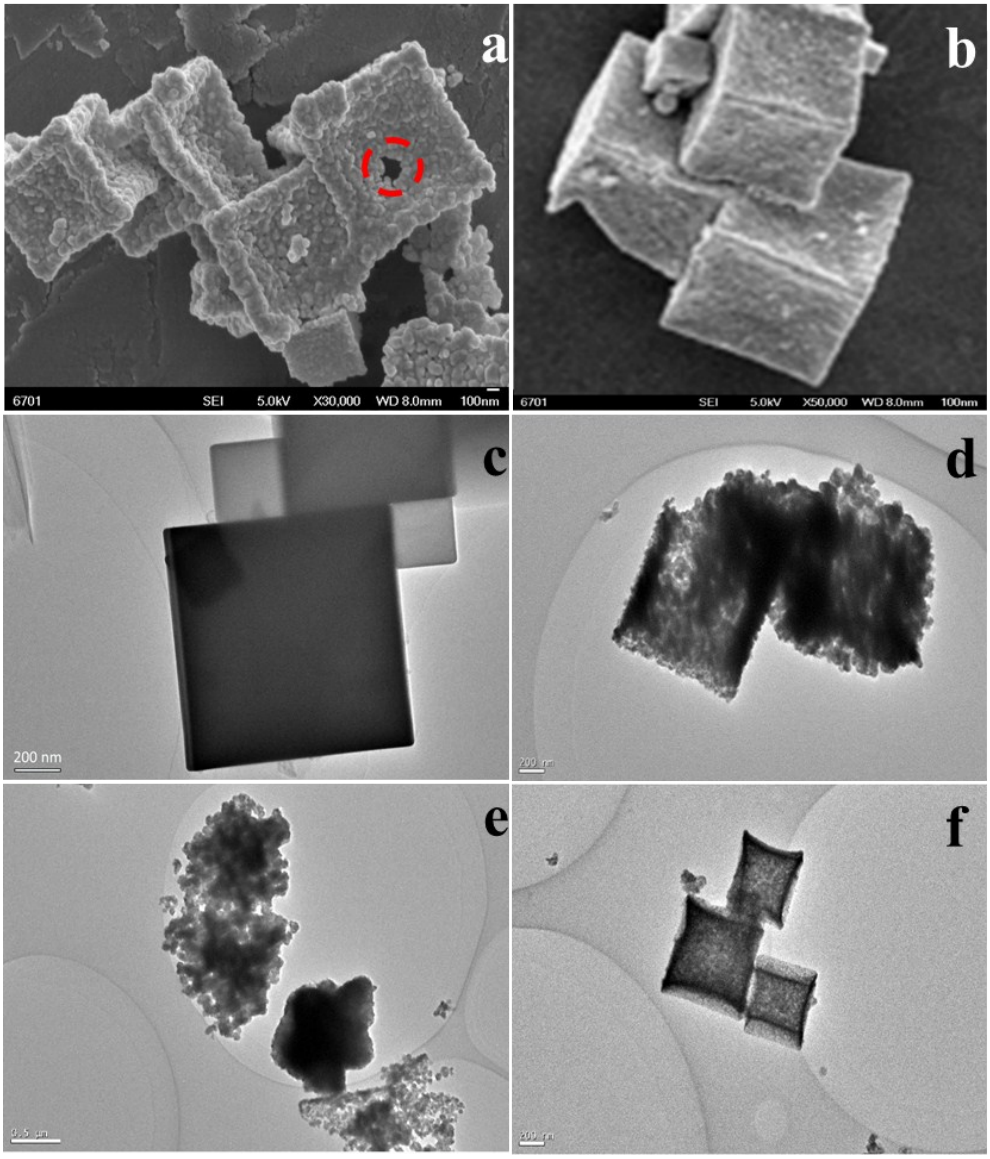

Figure S4. SEM images of a) the HC-CoInOx sample, b) C-CoInOx sample; TEM images of c) the CoIn-PBA cubes (unfired), d and e) C-CoInOx sample (fired at 450 °C), f) the HC-CoInOx sample (fired at 450 °C)

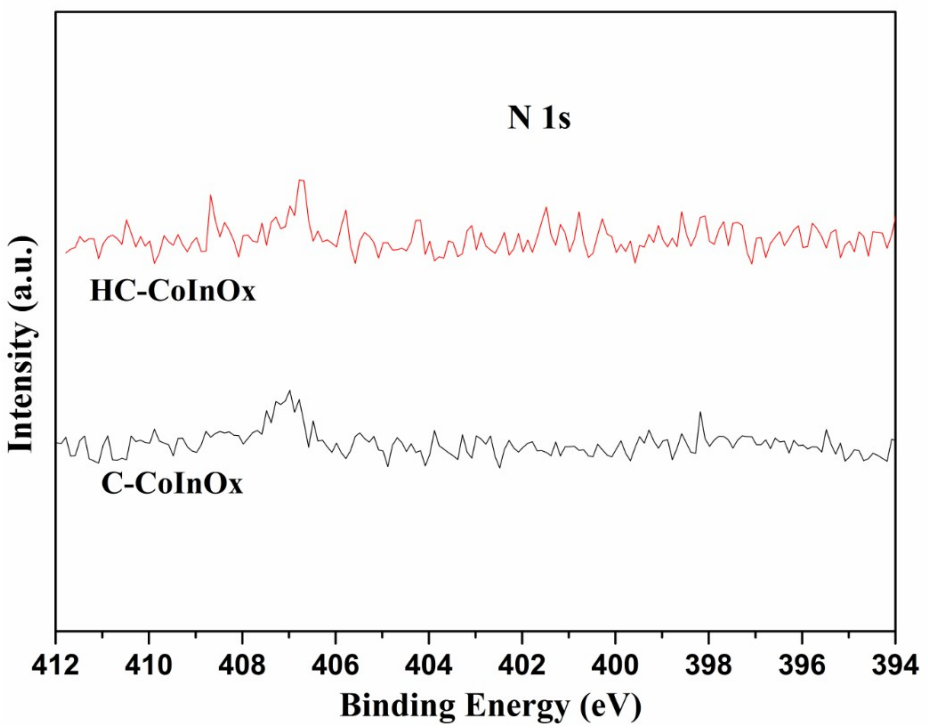

Figure S5. N 1s XPS of the CoInOx catalysts

Table S1 Co chemical states of the CoInOx catalysts with different morphology

Catalysts	Sat. 1	$Co^{2+}2p_{3/2}$	$Co^{3+}2p_{3/2}$	Sat. 2	$Co^{2+}2p_{1/2}$	$Co^{3+}2p_{1/2}$	$Co^{3+}/(Co^{2+}+Co^{3+})$
C-CoInOx	123629.1	124414.9	122673.2	123582.4	128762.2	124621.5	49.4
HC-CoInOx	65839.7	66184.2	65108.7	65886.5	67912.9	66413.1	49.5

Table S2 The content of each element in the CoInOx catalysts with different morphology

Catalysts	Total content (wt.%)[a]			
	Co	In	Na	Si
C-CoInOx	58.7	3.5	-	-
HC-CoInOx	60.5	4.2	0.2	<0.01μg/mL

[a] the element content was determined by continuous light source atomic absorption spectrometer and ICP-OES (Inductively coupled plasma optical emission spectrometry) analysis.

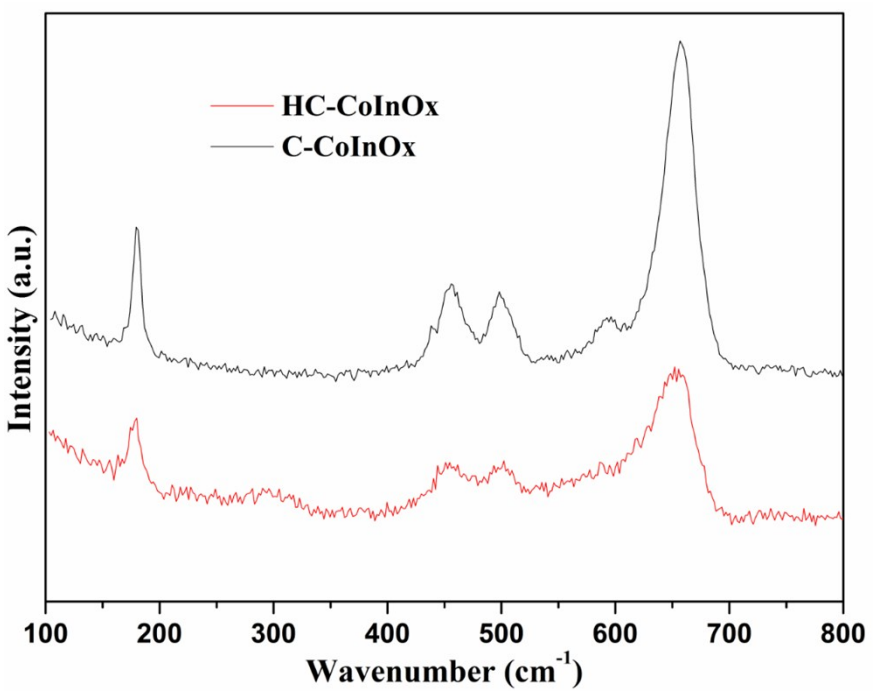

Figure S6. Raman spectrum of the CoInOx catalysts

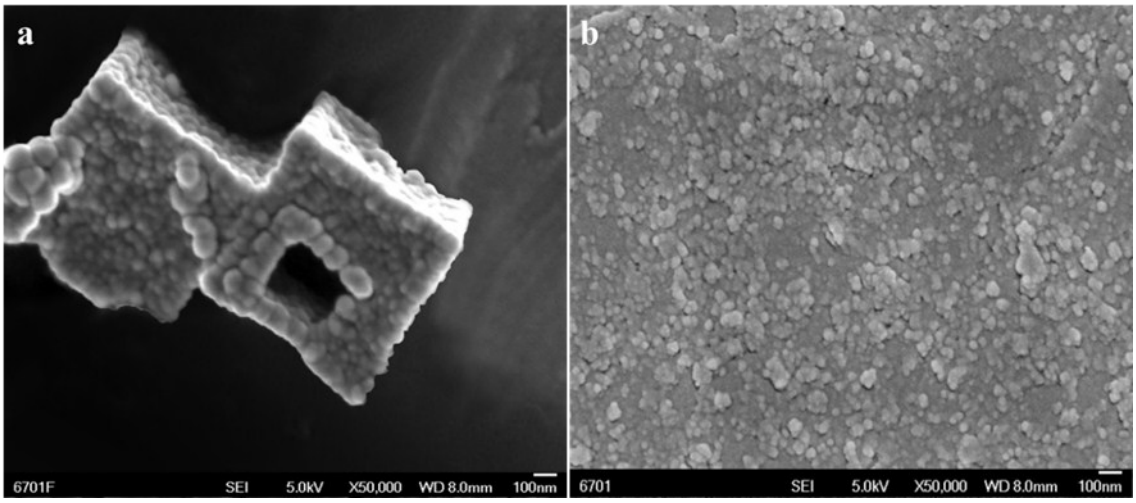

Figure S7. SEM images of hollow porous (a) CoOx and (b) InOx catalysts through the same SiO_2 template method