Electronic Supplementary Material (ESI) for Nanoscale.

Supporting Information

Research Advances of Chlorinated Benzene-containing Compound Oxidation Catalyzed by Metal Oxides: Activity Enhanced Strategies and Reaction Facilitated Mechanism

Ning Luo [a,1], Fengyu Gao [a,1], Du Chen [a], Erhong Duan [b], Zaharaddeen Sani [c], Honghong Yi [a], Xiaolong Tang [a,*]

[a] Beijing Key Laboratory of Resource-oriented Treatment of Industrial Pollutants, School of Energy and Environmental Engineering, University of Science and Technology Beijing, Beijing, 100083, PR China

[b] School of Environmental Science and Engineering, Hebei University of Science and Technology, Shijiazhuang, Hebei 050018, PR China

[c] Department of Science Laboratory Technology, Federal Polytechnic Daura, Katsina State, Nigeria.

* Corresponding author: E-mail address: txiaolong@126.com

[1] These authors contributed equally to this work.

Table S1 Summary of advantages and disadvantages of the CBCs degradation technologies

Technology	Principle	Conversion/%	Temperature/°C	Advantage	Disadvantage	Ref
Adsorption	Transferring CBCs from the air to the solid phase via high specific surface area adsorbent.	80~90	＜60	Efficient, simple, reusable	Adsorbent needs to be regenerate	1, 2
Membrane separation	CBCs can be separated by permeating the membrane under certain pressure	90~99	Normal temperature	Simple process	Less gas treatment	3
Condensation method	CBCs are condensed into droplets and separated from the gas	70~85	Low temperature	Low cost	Low efficiency, large equipment	4
Thermal incineration	CBCs are destroyed under high temperature heating or incineration conditions to form CO_2, HCl and H_2O.	95~99	800~1200	Simple, practicable	High energy consumption, high cost, secondary pollution	5-7
Photo-catalytic decomposition	Using nano-semiconductor catalysts and ultraviolet (UV) light to convert CBCs in indoor air into benign and odourless constituents-water vapor (H_2O) and carbon	-	Illumination	Completely inorganic, few by-products, low investment cost	Small processing capacity, high concentration	8-11

	dioxide (CO_2)					
Biological degradation	CBCs can be degraded under the action of microorganisms by selecting appropriate microbial strains.	60~95	Normal temperature	Potential, less investment, thoroughly degradation	Large space demand, Slow efficiency	12-14
Hydrothermal degradation	Degraded by hydrolysis and free radical reaction under high temperature and pressure.	~99	500	Large processing capacity, high efficiency, good prospects	Slow efficiency, secondary chlorination	15
Catalytic oxidation	Degradation of contaminants through active sites and oxygen vacancies on the catalyst surface.	＞98	200~400	Low temperature, low energy consumption, high efficiency, no secondary pollution	High cost, deactivation of catalyst	16-18

Table S2 Comparison of different kinds of catalysts for CBCs

Categories	Catalysts	Reactant	Concentration/ppm	Space velocity	T_{90}/°C	Advantage	Disadvantage	Ref
Supported Noble Metal Catalyst	$Pd/\gamma\text{-}Al_2O_3$	o-DCB	450 ppm	15 000 h^{-1}	482	low ignition temperature, high catalytic activity	inactivated by Cl poisoning, loss of active components in high temperature, formation of oxychloride, production of poly-chlorinated by-products, expensive	19
	Pd/SiO_2	o-DCB	450 ppm	15 000 h^{-1}	526			
	Pd/ZSM-5	o-DCB	450 ppm	15 000 h^{-1}	474			
	$Pt\text{-}4W/CeO_2$	CB	1000 ppm	60 000 h^{-1}	327			20
	$Pt\text{-}4W/CeO_2$	o-DCB	1000 ppm	60 000 h^{-1}	343			
	$Pt_{0.5}R_{u0.5}$/m-HZ	CB	1000 ppm	40 000 mL $g^{-1}h^{-1}$	270			21
Perovskite type Catalyst	Sm-Mn perovskite@mullite composite	CB	1000 ppm	30 000 mL $g^{-1}h^{-1}$	290	adjustable structural defects, rich reactive oxygen species,	high reaction temperature, reactants blocking the active site, high temperature change the catalyst structure, loss of active components.	22
	$Pd/LaMnO_3$	CB	1000 ppmv	12 000 mL $g^{-1}h^{-1}$	243(T_{50})			23
	$Pd/LaFeO_3$	CB	1000 ppmv	12 000 mL $g^{-1}h^{-1}$	270(T_{50})			
	$Pd/LaAlO_3$	CB	1000 ppmv	12 000 mL $g^{-1}h^{-1}$	348(T_{50})			
	$Pd/LaCoO_3$	CB	1000 ppmv	12 000 mL $g^{-1}h^{-1}$	360(T_{50})			
	$Pd/LaNiO_3$	CB	1000 ppmv	12 000 mL $g^{-1}h^{-1}$	408(T_{50})			
Molecular Sieve	$Ce_4\text{-}Co_6$ HMS	CB	1000 ppm	30 000 h^{-1}	440	good activity and selectivity, abundant	expensive, easy to be inactivated in the	24
	Pt/H-ZSM5	CB	2000 ppm	18 600 h^{-1}	~335			25

Catalyst	Pt/H-beta	CB	2000 ppm	18 600 h^{-1}	~340	pore structure and acidic sites, strong ability to resist Cl inactivation.	presence of water.	
	10% CrNd(6:1)/KL-NY	CB	1000 ppm	20 000 h^{-1}	260			26
Transition Metal Catalyst	V_2O_5/HNTs	CB	100 ppm	37 000 h^{-1}	~330	environmentally friendly, low cost, easy to obtain, good catalytic performance, good stability, strong REDOX capacity, good chlorine resistance	Some metal oxides are prone to oxychlorination (Deacon) reactions, generate toxic by-products, required to increase the anti-Cl toxicity	27
	VTiS	CB	100 ppm	37 000 h^{-1}	~345			28
	3V-10W/TiO_2	CB	200 ppm	25 000 h^{-1}	200			29
	V_2O_5-MO_3/TiO_2	CB	200 ppm	60 000 h^{-1}	200			30
	γ-MnO_2	CB	500	10 000 h^{-1}	175			31
	MnOx/CeO_2	CB	1000	15 000 h^{-1}	236			32
	CeMnOx	o-DCB	1000	15 000 h^{-1}	~340			33
	α-Fe_2O_3	o-DCB	100 ppmv	18 000 mL $g^{-1}h^{-1}$	450($\mathbf{T_{70}}$)			
	$CaCO_3$/α-Fe_2O_3	o-DCB	100 ppmv	18 000 mL $g^{-1}h^{-1}$	~400			34

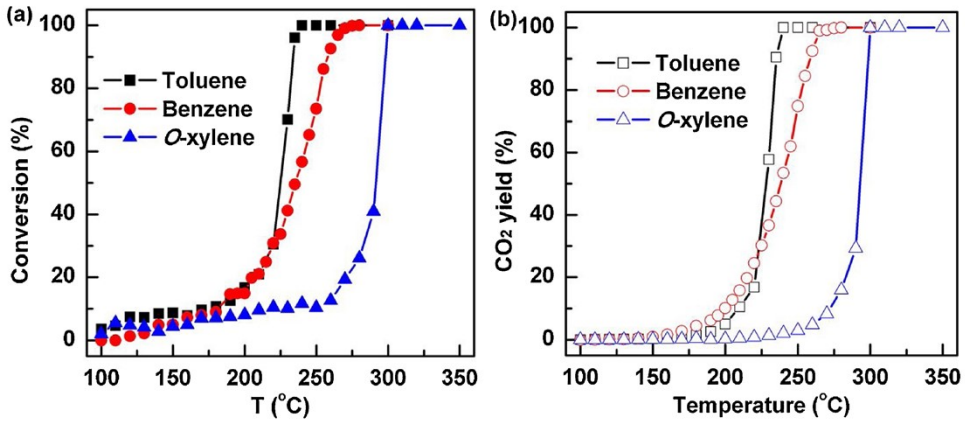

Figure S1. The activity test in catalytic oxidation of VOCs at: Conversion of different aromatic VOCs and CO_2 yield over 3Mn1Ce. (WHSV of 60000 mL g^{-1} h^{-1}) [35] Copyright 2018 American Chemical Society

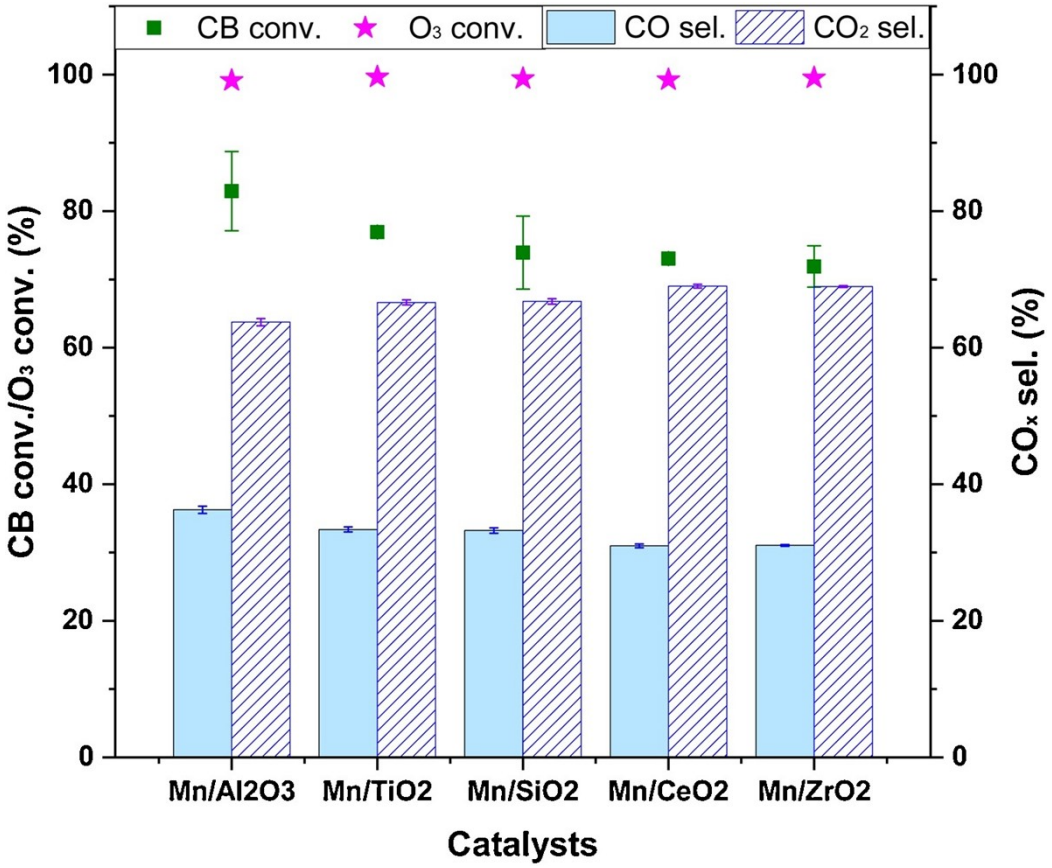

Figure S2 Catalytic performance of CB ozonation over MnOx with different supports.[36]

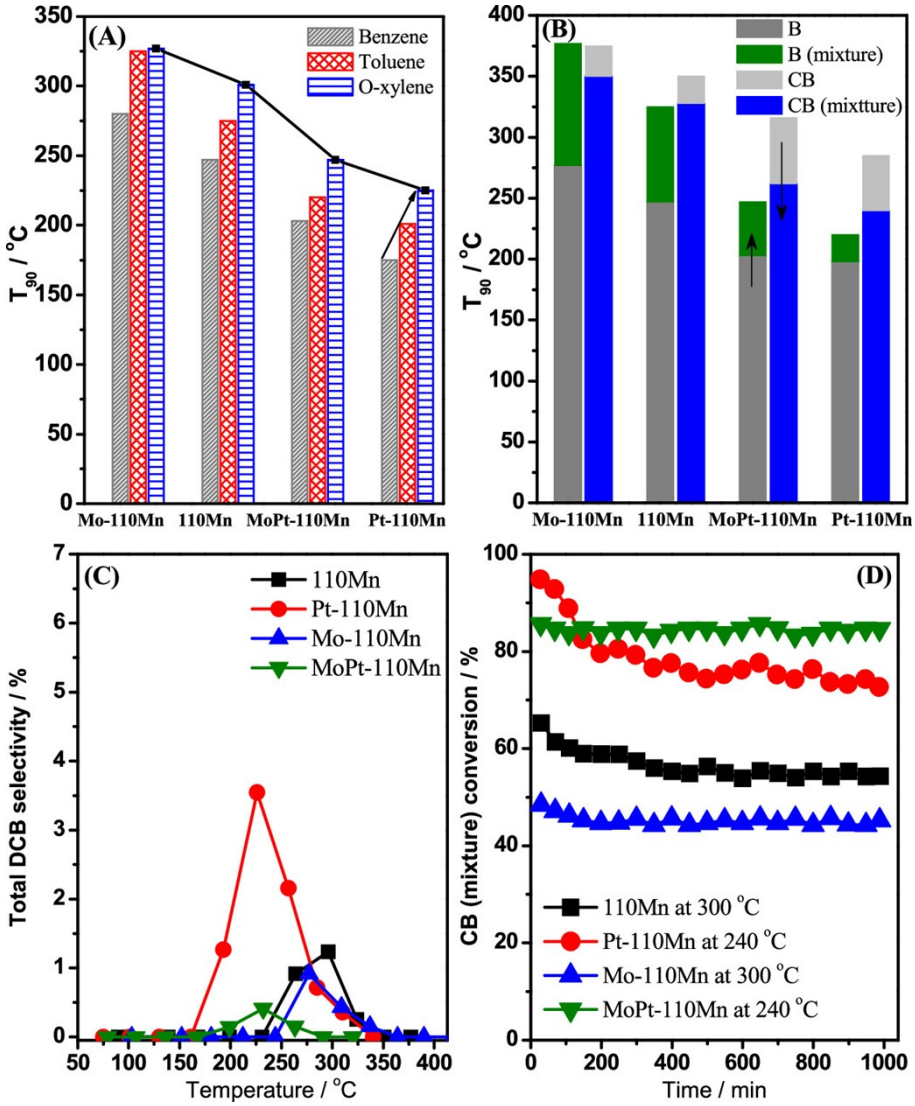

Figure S3 Catalytic performance of prepared Mn-based catalysts for catalytic oxidation of BTX (A) and the mixed CB and benzene (B), DCB selectivity (C), and durability (D) for catalytic oxidation of the mixed CB and benzene.[37] Copyright 2021 American Chemical Society

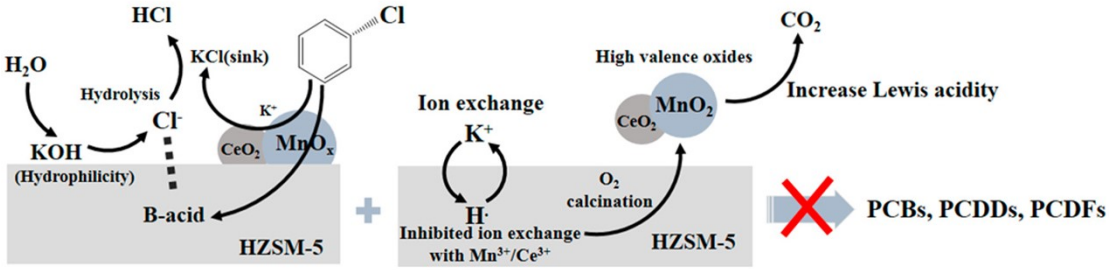

Figure S4 Possible reaction mechanism of CB oxidation on $Mn_xCe_{1-x}O_2$/HZSM-5.[38] Copyright 2018 American Chemical Society

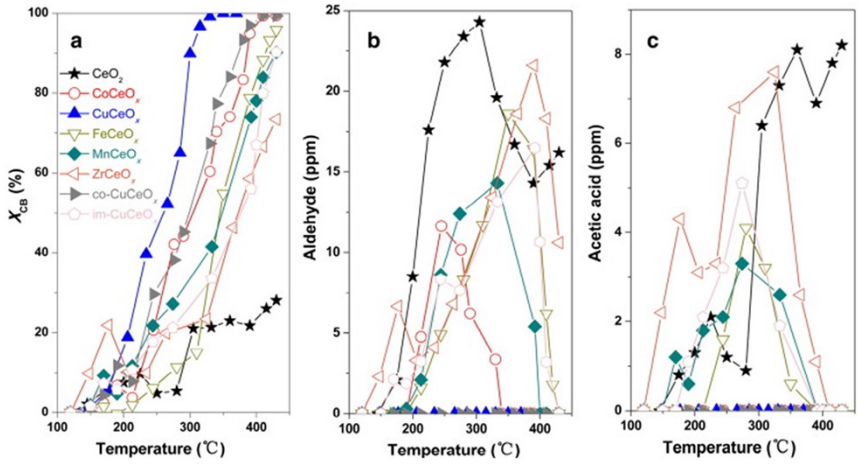

Figure S5 CB conversion and primary reaction byproduct distribution over synthesized catalysts.

[39] Copyright 2015 Elsevier

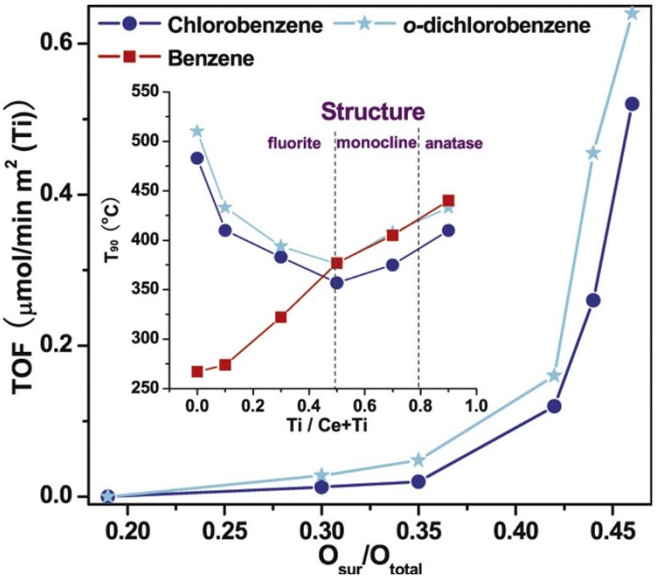

Figure S6 Effect of structure on CBCs removal performance on Ce-Ti mixed oxide catalysts. [40]

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