

Supplementary data

Enhancing the selective conversion of alcohols to aldehydes using oxygen over heterogeneous photocatalysts — critical factors with emphasis on benzyl alcohol

Nosaibeh Nosrati-Ghods¹, Lidija Čuček², Eric van Steen¹

¹ Chemical Engineering Department, Faculty of Engineering and the Built Environment, University of Cape Town, Cape Town, South Africa

² Faculty of Chemistry and Chemical Engineering, University of Maribor, Maribor, Slovenia

Table 1. Summary of oxidation of alcohols to carbonyl compounds – O₂ as oxidant

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
ZnIn ₂ S ₄ microsphere	Solvothothermal	>99	100	2.67 eV	Oxygen	300 W Xenon lamp, λ>420 nm	2 h	Ethanol	Room temperature	0.1 MPa of O ₂	63 m ² g ⁻¹	benzyl alcohol: 0.1 mmol, catalyst: 8 mg, reaction volume (benzotrifluoride): 1.5 mL	-	-	[1]
		98.3	58	2.56 eV				H ₂ O			98 m ² g ⁻¹		0.43	53.75	
		94	69	NA							NA	Benzyl alcohol: 0.1 mmol, catalyst: 8 mg, reaction volume (benzotrifluoride): 1.5 mL	0.39	48.75	[2]
ZnIn ₂ S ₄	Hydrothermal	90	45	2.34-2.48 eV			3 h		80 °C		33.49 m ² g ⁻¹		0.3	37.5	[3]
ZnIn ₂ S ₄ +30mg glucose (C/ZIS-0.03)	Solvothothermal	95	70	2.72 eV			2 h	Benzotrifluoride	Room temperature		32.12 m ² g ⁻¹		0.6	75.0	
TiO ₂	Microwave solvothothermal,	60	9	3.08	Oxygen	300 W Xenon lamp, λ > 460 nm	4 h	Benzotrifluoride	30 ° C	1 atm of O ₂	57.77 m ² g ⁻¹	Catalyst: 10 mg, benzyl alcohol: 0.1 mmol, solvent of reaction volume (benzotrifluoride/trifluorotoluene): 1.5 mL	0.024	2.4	[4]
Pt-TiO ₂		>99	90	3.05							56.99 m ² g ⁻¹		0.57	57	
Au-TiO ₂		>99	28	3.03							59.15 m ² g ⁻¹		0.082	8.2	
Ag-TiO ₂		98	18	3.04							58.84 m ² g ⁻¹		0.05	5	
Pd-TiO ₂		97	40	3.05							54.38 m ² g ⁻¹		0.13	13	

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
RuO ₂ /TiO ₂ NB	Hydrothermal, deposition-	98	99	NA	Air	UV and visible	5 h	water	240 °C	Atmospheric pressure	35.91 m ² g ⁻¹	Catalyst: 20 mg, benzyl alcohol: (20 µL min ⁻¹ , WHSV of 63 h ⁻¹)	0.92	46	[5]
RuO ₂		55	60	2.20							NA		0.183	9.15	
TiO ₂ NB		70	10	3.15							20.36 m ² g ⁻¹		0.021	1.05	
P25		69.2	11	NA							NA		0.0233	1.15	
0.95Ru/3DOM BiVO ₄ -Ar-300	Post-thermal treatment	100	78	2.41 eV	Ar atmosphere	300 W Xenon lamp, λ≥420 nm	4 h	Acetonitrile	300 °C	Atmospheric pressure	25.2 m ² g ⁻¹	Photo- catalyst: 10 mg, reaction volume (acetonitrile containing benzyl alcohol): 6 mL, phenylethanol or p-nitrobenzyl alcohol (C ₀): 0.02 mol L ⁻¹	0.38	38	[6]
Bi ₂ MoO ₆	Solvothetmal, photodepo	99	65	2.6	Oxygen	λ > 420 nm	6 h	Glycerol	20 °C	0.1 MPa of O ₂	20 m ² g ⁻¹	Catalyst 10 mg, benzyl alcohol 0.1 mmol, reaction volume (C ₆ H ₅ CF ₃): 1.5 mL, metal loading 0.3 wt%.	0.175	17.5	[7]
Pt/Bi ₂ MoO ₆ -glycerol		95	87	NA							NA		0.34	34.0	
Ni-OTiO ₂	Sol-gel	99	93	NA	Excess oxygen defects	300 W Xenon lamp	1 h	Benzotrifluoride	NA	NA	NA	Catalyst: 80 mg reaction volume: 0.5 mmol BA and 5 mL of BTF were mixed in a quartz glass bottle (40 mm × 25 mm) placed in the reactor	2.66	33.25	[8]
Ni-TiO ₂		NA	52										0.73	9.125	
O ₂ -TiO ₂		~98	64										1.02	12.75	
TiO ₂		~98	11										0.11	1.375	
W ₁₀ O ₄ ⁻³²	Wet impregnation	97	30		Oxygen	300 W Xenon lamp, λ > 300 nm	20 min	CH ₃ CN	5–10 °C	NA	NA	Catalyst: 5.5 × 10 ⁻⁴ M (36.5 mg), CH ₃ CN: 4 mL, substrate: 0.05 M	1.08	29.6	[9]

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
WO ₃ (7.6)/TiO ₂	Impregnation	56	50	3.02	Oxygen	450 W high-pressure mercury lamp, $\lambda > 350$ nm	5 h	Water	298 °K	1 atm of O ₂	53.1 m ² g ⁻¹	Benzyl alcohol: 0.1 mmol, reaction volume (water): 5 mL, catalyst: 5 mg, light intensity at 350–400 nm: 2.81 mW cm ⁻²	0.14	28	[10]
WO ₃		61	8	2.8			24 h				3.0 m ² g ⁻¹		0.0035	0.7	
TiO ₂		13	50	3.13			9 h				54.0 m ² g ⁻¹		0.077	15.4	
TiO _{1.966} N _{0.034}		100	66.3	E _{TiO1.966N0.034} = 2.28 eV E _{TiO2} = 3.2 eV	Oxygen	300 W Xenon arc lamp with cutoff and IR filter, $\lambda \geq 420$ nm	2 h	Acetonitrile	NA	NA	NA	reaction volume (H ₂ O/acetonitrile): 5 ml, benzyl alcohol: 10 mmol, photocatalyst: 20 mg. The photoreactivity runs were performed in a test tube (45 ml).	0.54	27	[11]
		>99	100				4 h						-	-	
Bi ₂ WO ₆	One-step hydrothermal	99/98	58/98	2.81	Oxygen	300 W Xenon arc lamp	10 h/22 h	Water	Room temperature	0.1 MPa of O ₂	NA	Alcohols: 0.1 mmol, catalyst: 8 mg, reaction volume (ultra-pure water): 1.5 mL.	0.087/ 0.178	10.88/ 22.25	[12]

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area		Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
Co _x Ni _{1-x} Fe ₂ O ₄ , x=0	Sol-gel	94.9	7.9		Oxygen	300-W Xenon lamp, visible light/dark	6 h	Acetonitrile	Room temperature	Atmospheric pressure of O ₂	37.9 m ² g ⁻¹		Benzyl alcohol: 9.6 mmol, reaction volume (acetonitrile): 2.0 mL, catalyst: 3.0 mg	0.014	4.67	[13]
Co _x Ni _{1-x} Fe ₂ O ₄ , x=0.1		92.7	12.4								38.4 m ² g ⁻¹			0.022	7.33	
Co _x Ni _{1-x} Fe ₂ O ₄ , x=0.3		90.1/ 98.3	18.9/ 1.8								37.5 m ² g ⁻¹			0.035/ 0.003	11.67 /1.01	
Co _x Ni _{1-x} Fe ₂ O ₄ , x=0.5		74.9	20.3								38.2 m ² g ⁻¹			0.038	12.67	
Co _x Ni _{1-x} Fe ₂ O ₄ , x=0.7		63.8	23.2								37.2 m ² g ⁻¹			0.044	14.67	
Co _x Ni _{1-x} Fe ₂ O ₄ , x=0.9		61.8	24.9								37.6 m ² g ⁻¹			0.05	16.67	
Co _x Ni _{1-x} Fe ₂ O ₄ , x=1.0		58.4	28.7								38.0 m ² g ⁻¹			0.056	18.67	
CeO ₂	Hydrothermal	~97	~5	NA		300 W Xenon arc lamp with a UV-cutoff filter (λ≥ 420 nm)	4 h	Acetonitrile	Room temperature	1 bar	S _{BET} (m ² g ⁻¹)	Pore size	Photocatalyst: 20 mg reaction volume (acetonitrile):8 mL, benzyl alcohol solution: 83 μL and 0.8 mmol under ultrasound irradiation	0.013	0.65	[14]
CdS		~96	7.9	2.4							167.1	3.3		0.02	1.0	
CdS@TiO ₂		~98	17.3	NA							8.1	17.3		0.047	2.35	
CdS@CeO ₂ -90		>99	~25								89.2	8.1		0.072	3.6	
CdS@CeO ₂ -180		>99	75.3								77.4	8.7		0.35	17.5	
											66.6	9.7				

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
Bi ₁₂ O ₁₇ Cl ₂	Hydrothermal	>99	44	2.43	Oxygen	500 W Xenon lamp with a cut-off filter ($\lambda > 420$ nm)	8 h	Acetonitrile	50 °C by water bath	Atmospheric pressure of O ₂	NA	Bi ₁₂ O ₁₇ Cl ₂ : 50 mg, reaction volume (acetonitrile): 10 mL. 20 mL round bottom flask was selected	0.72	14.4	[15]
CsPbBr ₃ /P25	Wet-impregnation	>99	50	2.34	Oxygen	$\lambda \geq 420$ nm	20 h	Toluene	80 °C	1 bar of O ₂	NA	Benzyl alcohol: 0.1M, reaction volume (toluene): 5 mL, catalyst: 25 mg	0.35	14.0	[16]
CsPbBr ₃		NA	3.3	NA									0.014	0.56	
P25		~95	~24	3.0									0.0017	0.068	
P25	Hydrothermal, photo-	69	11	NA	Oxygen	UV and visible	5 h	Water	240 °C	Atmospheric pressure of O ₂	NA	Catalyst: 20 mg	0.023	1.15	[17]
TiO ₂ NBs		70	10										0.021	1.05	
Ru/P25		75.3	58.3										0.175	8.75	
Ru/TiO ₂		81	72										0.25	12.5	
TiO ₂ @Pt@CeO ₂		35	39										0.099	12.38	
CdS–UiO–66(NH ₂)	Photodeposition	100	31	NA	Oxygen	Visible-light ($\lambda \geq 420$ nm)	4 h	Benzotrifluoride		0.1 MPa of O ₂	E _{CdS-U6-NH2} : 322.61 m ² g ⁻¹	Alcohol: 0.1 mmol, UiO–66(NH ₂): 8 mg, reaction volume (BTF): 1.5 mL	0.093	11.63	[18]
UiO–66(NH ₂)		100	~20								E _{UiO-66-NH2} : 756.04 m ² g ⁻¹		0.056	7.0	
CdS		100	~10	2.4							NA		0.03	3.75	

Catalyst/strategy				Band gap (eV)							Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
Selectivity (%)	Conversion (%)				Oxidant	Radiant	Time	Solvent	Temp	Pressure					
Pt@CeO ₂	Impregnation, hydrothermal	>98	37		Oxygen	300 W Xenon arc lamp with a filter (λ <420 nm)	5 h	Benzotrifluoride	Room temperature	0.1 MPa of O ₂	NA	Benzyl alcohol: 0.1 mmol, catalyst: 8 mg, reaction volume (benzotrifluoride (BTF)): 1.5 mL	0.092	11.5	[19]
Nanosized CeO ₂		NA	4.2	0.0086									1.075		
Blank CeO ₂			1.4	0.003									0.375		
Commercial anthra-quinone dye Alizarin Red (AR) as the sensitizer and TEMPO as the cocatalyst in a suspension of TiO ₂		98	80	E ⁰ vs. NHE (V)	O ₂ , nitroxyl radical TEMPO	Visible-light irradiation (λ>450 nm)	18 h	Benzotrifluoride (BTF)	Ambient temperature	0.1 Mpa of O ₂	NA	Alcohol: 0.1 mmol, AR/TiO ₂ (8 mg, containing 6.5×10 ⁻⁴ mmol AR), TEMPO: 2×10 ⁻³ Mmol, reaction volume (BTF): 1.5 mL	0.09	11.25	[20]
				E ⁰ _{O2/O2·-:} - 0.15V E _{cb, anatase:} - 0.5V E _{AR[•]/AR⁺·-:} - 1.57V E _{TEMPO[•]/TEMP:} 0.64V E _{AR[•]/AR:} 0.79V											
		98	43											Scaled-up reaction, substrate: 5 mmol, AR/TiO ₂ : 40 mg, TEMPO: 0.01 mmol, reaction volume (BTF): 30 mL	
MIL-100(Fe)	Solvothermal	100	3.3	1.80		Visible-light (λ > 520 nm)	5 h	Water	Room temperature		1598.8 m ² g ⁻¹	Photocatalysts weight: 16 mg, reaction volume (toluene): 3 ml, benzyl alcohol: 0.2 mmol	0.007	0.44	[21]
CdS		95.5	40	2.44							66.1 m ² g ⁻¹		0.102	6.375	
CdS-MIL-100(Fe)-7.5		97.4	42.5	2.37							71.3 m ² g ⁻¹		0.111	6.94	
CdS-MIL-100(Fe)-15		98.1	45.8	2.22							74.9 m ² g ⁻¹		0.122	7.625	
CdS-MIL-100(Fe)-30		98.5	46.7	2.16							95.3 m ² g ⁻¹		0.126	7.875	
CdS-MIL-100(Fe)-60		99.2	54.3	2.23							326.9 m ² g ⁻¹		0.157	9.812	
CdS-MIL-100(Fe)-120		97.8	44	2.28							847.6 m ² g ⁻¹		0.116	7.25	
CdS-MIL-100(Fe)-240		97.3	39.9	2.31							1536.2 m ² g ⁻¹		0.1	6.25	

Catalyst/strategy			Selectivity (%)	Conversion (%)	Band gap (eV)		Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
Au/BiOCl with oxygen vacancy $\lambda \geq 420$ nm		Microwave-heating	>99	75.6	NA	Oxygen	300 W Xenon lamp with a 420 nm cutoff filter	8 h	Acetonitrile	25 C	0.1 MPa of O ₂	NA	Photocatalyst: 50 mg, reaction volume (acetonitrile): 10 mL, benzyl alcohol: 0.5 mmol in a 20 mL round- bottomed flask.	0.18	3.6	[22]	
Au/BiOCl without oxygen vacancy			93.9	7.3										0.0095	0.19		
BiOCl			80.3	31.8										0.048	0.96		
Bi ₂₄ O ₃₁ Cl ₁₀		Microwave-calcination	>99	>99	2.51	Air	Blue LED irradiation, 20 mWcm ⁻²	2.5 h	Acetonitrile	Ambient temperature	Atmospheric pressure without extra air/oxygen purging	16.34 m ² g ⁻¹	Photo-catalyst: 200 mg, Benzyl alcohol acetonitrile solution in a beaker: 50 mL of 0.5 mmol L ⁻¹ .	1.84	9.2	[23]	
Bi ₂ MoO ₆ spheres	V _o -rich	Solvothermal	99	38.2	2.36	Oxygen	$\lambda \geq 400$ nm	4 h	Benzotrifluoride	298 K	1 bar of O ₂	48.1 m ² g ⁻¹	Alcohol: 0.1 mmol, catalyst: 16 mg, reaction volume (benzotrifluoride) (BTF): 1.5 mL	0.12	7.5	[24]	
	V _o -po		91	7.1	2.68							14.57 m ² g ⁻¹		0.018	1.125		
ZnTi-2/1		Modified co-precipitation	>99	38.8	3.25 eV	Oxygen	Xenon lamp	4 h	Benzotrifluoride	298 K	1 bar of O ₂	106.5 m ² g ⁻¹	benzyl alcohol: 0.1 mmol, photocatalyst: 20 mg, reaction volume (benzotrifluoride): 1.5 ml	0.123	6.15	[25]	
ZnTi -3/1			>99	31.8								88.83 m ² g ⁻¹		0.096	4.8		
ZnTi -4/1			>99	27.5								80.04 m ² g ⁻¹		0.08	4.0		
P25			>99	16.7	NA							NA		0.046	2.3		

Catalyst/strategy				Band gap (eV)							Surface area	Other						
		Selectivity (%)	Conversion (%)		Oxidant	Radiant	Time	Solvent	Temp	Pressure			Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References			
0.5%Pt-TiO ₂ -5	Incipient wetness impregnation	>99	10.8	NA	Oxygen	500 W Xenon lamp, 420 nm < λ < 800 nm	4 h	Toluene	Room temperature	1 bar of O ₂	NA	Benzyl alcohol: 20 μl, reaction volume (toluene): 2 mL, catalyst: 10 mg, sample bottle: 10 mL	0.03	3	[26]			
1%Pt-TiO ₂ -5		>99	13.4								0.036		3.6					
2%Pt-TiO ₂ -5		>99	20.1								0.06		6					
2%Pt-P25		>99	9.23								0.024		2.4					
TiO ₂ -5 (5 h hydrothermal)		>99	8.1								102.03		0.02	2				
P25		98	6.42								NA		0.016	1.6				
AgBr@Ag@TiO ₂ -0.325	Double-jet precipitation, hydrolyzing TBOT in ethanol solution, hydrothermal	98	73	NA	Oxygen	Visible light irradiation (λ> 420 nm)	6 h	CH ₃ CN, Benzotrifluoride	Room temperature	1 bar of O ₂		Catalyst: 50 mg, benzyl alcohol: 104 μL, reaction volume (acetonitrile): 50 mL	0.22	4.4	[27]			
Blank TiO ₂		>95	7.2														0.009	0.18
AgBr@Ag		>95	15.8														0.02	0.4
AgBr@Ag@TiO ₂ -0.30		>95	73														0.16	3.2
AgBr@Ag@TiO ₂ -0.325		>95	83														0.22	4.4
AgBr@Ag@TiO ₂ -0.35		>95	88														0.26	5.2
AgBr@Ag@TiO ₂ -0.375		>95	40														0.06	1.2
							8 h				AgBr@TiO ₂ -0.35 after hydrothermal treatment	23.13	8.8 nm					
												S _{BET}						
												Pore size						

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
1D TiO ₂ (B)	Hydrothermal	79.3	2.0	2.8 eV	Oxygen	150W Halogen lamp	4 h	Solvent-free	30 °C	Atmospheric oxygen	S _{BET} : 43 m ² g ⁻¹ , BJH adsorption pore diameter: 9.5 nm, pore volume: 0.09 cm ³ g ⁻¹	Catalyst: 0.1 g, benzyl alcohol: 10 mL, oxygen: 90 mL min ⁻¹ . 1D TiO ₂ (B) nanowires supporting Pd nanoparticles were prepared	0.005	0.05	[28]
Pd/TiO ₂ (P25)	Sol-immobilized	73.8	68.8	NA			6h				NA		0.19	1.9	
Pd/TiO ₂ (B)		72.9	39.5	2.7 eV		Dark	2 h				0.25		2.5		
		70.3	55.6				2 h				0.41		4.1		
		69.7	81.9			4 h	0.43				4.3				
		89.7	2.7			4 h	0.0007				0.007				
Au–Pd/H ₂ Ti ₃ O ₇	Sol-immobilized	75.5	79.5	NA	Oxygen	150 W Halogen lamp	4 h	Solvent-free	90 °C	Atmospheric oxygen	NA	Benzyl alcohol: 10 mL, Pd loading: 1 wt %, catalyst: 0.1 g, O ₂ : 90 mL min ⁻¹	0.4	4.0	[29]
		72.6	91.0				6 h						0.0017	0.017	
Au/H ₂ Ti ₃ O ₇		70	95.0										0.0015	0.015	
Ag/H ₂ Ti ₃ O ₇		60	95.4										0.32	3.2	
Pd/H ₂ Ti ₃ O ₇		73.2	72.0				2.93							27.79 m ² g ⁻¹	
H ₂ Ti ₃ O ₇	Hydrothermal	89.2	2.2	3.04			4 h					Solvent-free	90 °C	Atmospheric oxygen	34.21 m ² g ⁻¹

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
0.8 BiOBr/Bi ₂ WO ₆	Hydrothermal for BiOBr	NA	30.9	E _{Bi₂WO₆} : 2.72 eV E _{BiOCl} : 3.35 eV E _{BiOBr} : 2.81 eV E _{BiOI} : 1.82 eV	Oxygen	300 W Xenon lamp	4 h	Benzotrifluoride	Room temperature	Atmospheric oxygen	NA	Catalyst: 20 mg, benzyl alcohol: 20 µL, reaction volume (benzotrifluoride (BTF)): 2.5 mL	0.09	4.5	[30]
CdS@15%SnO ₂	Hydrothermal, one-step solvent-assisted carrier	>99	80		Oxygen atmosphere	300 W Xenon arc lamp with a cutoff filter ($\lambda \geq 420$ nm)	8 h	Acetonitrile	Room temperature	1 bar of O ₂	38.1 m ² g ⁻¹	As-synthesized catalyst: 50 mg, reaction volume (acetonitrile): 20 mL, BA solution: 208 µL and 2 mmol	0.2	4.0	[31]
CdS		~90	40								19.5 m ² g ⁻¹		0.064	1.28	
g-C ₃ N ₄		>99	5.70/ 0.6	2.7	Air	450 W pulsed xenon lamp/dark	10 h	N-hexane	30 ± 3 °C	Atmospheric air	NA	Benzyl alcohol: 1 mmol, aniline: 1 mmol, weakly basic cesium carbonate (Cs ₂ CO ₃): 1.4 mmol, catalyst: 50 mg, reaction volume (solvent): 6 ml	0.006/ 0.0006	0.12/ 0.012	[32]
Ag/g-C ₃ N ₄ (1 wt%)		>99	12.3/ 7.2	NA									0.013/ 0.007	0.26/ 0.14	
Pd/g-C ₃ N ₄ (1 wt%)		>99	31.7/ 18.5										0.038/ 0.02	0.76/ 0.4	
Ag-Pd/g-C ₃ N ₄ (2 wt%, 1:1)		>99	86.7/ 30.2										0.2/ 0.036	4.0/ 0.72	

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References																								
UiO-66(NH ₂)	Facile solvotherm	100	21	NA	Oxygen	Visible light, λ ≥ 420 nm	4 h	Benzotrifluoride	NA	0.1 MPa of O ₂	E _{UiO-66(NH₂)} : 756.04 m ² g ⁻¹ E _{UiO-66} : 997.42 m ² g ⁻¹	Alcohol: .2 mmol, UiO-66(NH ₂): 16 mg, reaction volume (BTF): 3.0 mL	0.06	3.75	[33]																								
Rh ³⁺ /TiO ₂	Hydrothermal Crystallization in Organic Media	98	>99	NA	Oxygen	Visible light from blue LED	30 h	NA	NA	NA	<table><tr><td>TiO₂, P25</td><td>TiO₂, HyCOM550</td><td>TiO₂, MT-150A</td><td>TiO₂, F-6</td><td>TiO₂, ST-01</td><td>Sample</td></tr><tr><td>54 m²g⁻¹</td><td>81 m²g⁻¹</td><td>95 m²g⁻¹</td><td>98 m²g⁻¹</td><td>260 m²g⁻¹</td><td>S_{BET}</td></tr><tr><td>Anatase</td><td>Anatase</td><td>Rutile</td><td>Anatase</td><td>Anatase</td><td>Phase</td></tr><tr><td>rutile</td><td></td><td></td><td>rutile</td><td></td><td></td></tr></table>	TiO ₂ , P25	TiO ₂ , HyCOM550	TiO ₂ , MT-150A	TiO ₂ , F-6	TiO ₂ , ST-01	Sample	54 m ² g ⁻¹	81 m ² g ⁻¹	95 m ² g ⁻¹	98 m ² g ⁻¹	260 m ² g ⁻¹	S _{BET}	Anatase	Anatase	Rutile	Anatase	Anatase	Phase	rutile			rutile			Rh ³⁺ -modified F-6 samples: 0.5 wt%, catalyst: 50 mg, reaction volume (distilled water): 5 cm ³ , test tube: 35 cm ³ , substrates: 33 mmol	0.15	3.0	[34]
TiO ₂ , P25	TiO ₂ , HyCOM550	TiO ₂ , MT-150A	TiO ₂ , F-6	TiO ₂ , ST-01	Sample																																		
54 m ² g ⁻¹	81 m ² g ⁻¹	95 m ² g ⁻¹	98 m ² g ⁻¹	260 m ² g ⁻¹	S _{BET}																																		
Anatase	Anatase	Rutile	Anatase	Anatase	Phase																																		
rutile			rutile																																				

Catalyst/strategy				Band gap (eV)							Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
		Selectivity (%)	Conversion (%)		Oxidant	Radiant	Time	Solvent	Temp	Pressure					
TiO ₂	Hydrothermal	>98	3.4	E _{cb} TiO ₂ : -1.09 eV E _{Pt} : 5.40 eV E _{Au} : 4.78 eV	Oxygen	300 W Xenon lamp, visible light, UV cut-off filter (λ> 420 nm)	8 h	Toluene	NA	Atmospheric oxygen	TiO ₂ nanorods (304 m ² g ⁻¹) as a dispersing agent and suitable support for metal particles in the hybrid system compared with the metal-modified samples (range=255–278 m ² g ⁻¹)	The facile photodeposition technique has advantages in terms of its short reaction time, low-cost equipment, and the use of light as the reducing agent. Catalyst: 50 mg, 20 mL of benzyl alcohol/toluene solution (0.05 M)	0.004	0.08	[35]
Au/TiO ₂	Deposition-precipitation	>98	16.3	0.022									0.44		
Pt/TiO ₂		>98	32.2	0.05									1.0		
Au ₁ Pt _{0.5} /TiO ₂		>98	56.8	0.1									2.0		
Au ₁ Pt ₂ /TiO ₂		>98	64.5	0.13									2.6		
Au ₁ Pt ₁ /TiO ₂		>98	65.3	0.13									2.6		
0.3rGO/C ₃ N ₃ S ₃	In situ two-step polymerization	100	45.9	NA	Oxygen	Visible light (λ > 420 nm)	8 h	Benzotrifluoride			BET surface areas are doubled to 193 m ² g ⁻¹ after the addition of 2.0 wt % rGO, compared to the pure polymer (94 m ² g ⁻¹)	Aromatic alcohols: 0.5 mmol, photocatalysts: 0.03 g, solvent of reaction volume (benzotrifluoride (BTF)): 2.5 mL	0.077	2.57	[36]
TiO ₂		92.7	24.3	0.035									1.17		
C ₃ N ₃ S ₃		100	28.2	2.76									0.04	1.33	
BiOCl/RGO/PCN	Polymerization of melamine at 550 °C,	>99	71.6	NA	Oxygen bubbling	500 W Xenon lamp	10 h	CH ₃ CN	Room temperature	NA	64.422 m ² g ⁻¹	Benzyl alcohol: 0.5 mmol, reaction volume (CH ₃ CN solvent): 10 mL, catalyst: 50 mg, O ₂ bubbling	0.126	2.52	[37]
pristine g-C ₃ N ₄		>99	19.2	6.399 m ² g ⁻¹							0.021		0.42		
protonated g-C ₃ N ₄		>99	30.4	37.931 m ² g ⁻¹							0.036		0.72		
pure BiOCl		>99	0.0	NA							0.0		0.0		
BiOCl/PCN		NA	55.2	57.068 m ² g ⁻¹							0.08		1.6		

Catalyst/strategy			Selectivity (%)	Conversion (%)	Band gap (eV)		Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
Cu ₂ MoS ₄ FNSs		Solvothermal	NA	18	1.65		Oxygen	500 W Xenon lamp	2 h	benzotrifluoride	Room temperature	NA	NA	Photocatalyst: 100 mg, benzyl alcohol: 0.1 mmol, reaction volume (benzotrifluoride): 1.5 mL	0.1	1.0	[38]
Cu ₂ MoS ₄ INSs				38	1.71										0.24	2.4	
1.6wt% Au/CdMoO ₄		chemical	100/100	19.5/58	E _{CdMoO4} : 3.5		O ₂ or N ₂	300 W Xenon arc lamp with a 420 nm filter	2 h/18 h	benzotrifluoride	Room temperature	1 bar of O ₂ or N ₂	NA	Catalyst: 50 mg, benzyl alcohol: 10 μL, reaction volume (benzotrifluoride): 1.5 mL	0.11/0.05	2.2/1.0	[39]
		Hydrothermal, reduction															
Multi-Pd core@CeO ₂ shell nanocomposite		Hydrothermal	100	28		Oxygen		300 W Xenon lamp, λ > 420nm	20 h	Benzotrifluoride	Ambient temperature	0.1 MPa of O ₂	104 m ² g ⁻¹	Alcohol: 50 μmol, catalyst: 8 mg, reaction volume (benzotrifluoride): 1.5 mL	0.016	2.0	[40]
Supported Pd/CeO ₂			71	7									32 m ² g ⁻¹		0.004	0.5	
Fe ³⁺ /TiO ₂ /zeolite Y	SPD	Wet impregnation	90	57	3.05 (TiO ₂)	Oxygen		407	8 h	Acetonitrile	Room temperature	1 bar of O ₂	NA	C _{Benzyl-alcohol} = 1 mM in V _{Acetonitril} = 18 mL, C _{photocat.} =3g L ⁻¹ , 150 W Xe lamp, photocatalyst: 54 mg	0.1	1.85	[41]
					1.77 (Fe ³⁺)			701nm									
	SD		80	45	3.01 (TiO ₂)			412							0.075	1.39	
					1.82 (Fe ³⁺)			681 nm									
	PD		91	42	2.85 (TiO ₂)			435 nm							0.07	1.3	

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
g-C ₃ N ₄		99	3.1	NA	Oxygen	4 white LED lamps (10 W)	1 day	Benzotrifluoride	273 °K	Atmospheric oxygen	~10 m ² g ⁻¹	Catalyst: 10 mg	0.0013	0.13	[42]
POP-HE		99	33.6								387.7 m ² g ⁻¹		0.017	1.7	
10 wt% CdS/ g-C ₃ N ₄	Hydrothermal	>90	48	NA	N ₂ atmosphere	Visible light, λ > 420 nm	4 h	Benzotrifluoride	60 °C	0.5 MPa of reactor	7.1 m ² g ⁻¹	15 ml reaction volume of solution (benzotrifluoride as solvent) containing reactants and 0.1 g photocatalyst were put into a 100 ml reactor of Teflon-lined stainless-steel autoclave.	0.163	1.63	[43]
g-C ₃ N ₄		82.8	9.3	2.7							4.0 m ² g ⁻¹		0.024	0.24	
CdS		92.6	16.3	2.35							NA		0.044	0.44	
10 wt% CdS/ g-C ₃ N ₄	Thermal polymerization and hydro-thermal	93	48	NA	N ₂ atmosphere	Visible light, λ > 420 nm	4 h	Benzotrifluoride	60 °C	0.5 MPa of reactor	NA	Photocatalyst: 0.1 g, reaction volume (benzotrifluoride solution): 15 mL, benzyl alcohol: (2.55×10 ⁻² mol L ⁻¹), nitrobenzene: (8.5×10 ⁻³ mol L ⁻¹), Volume of reactor: 100 mL	0.163	1.63	[44]
g-C ₃ N ₄		83	9.3	2.7									0.024	0.24	
CdS		92	16.3	2.35									0.044	0.44	
In ₂ S ₃	Hydrothermal	99.8	41.5	2.0–2.3 eV	Oxygen	300 W Xenon lamp, λ > 420 nm	4 h	Benzotrifluoride	70 °C	0.1 MPa of O ₂	47.4 m ² g ⁻¹	Alcohol: 0.5 mmol, catalyst: 80 mg, reaction volume (benzotrifluoride): 15 ml	0.13	1.625	[45]

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
NH ₂ -MIL-125(Ti)	Hydrothermal	99	>85	2.88	Oxygen	White-light LED lamps in the range of 420–780 nm	40 h	Acetonitrile	Room temperature	1 atm of O ₂	1176.1 m ² g ⁻¹	Photocatalysts: 30 mg, reaction volume (MeCN): 6 ml, benzyl alcohol: 0.3 mmol	0.047	1.57	[46]
CdS-MIL-125(Ti)	Photochemical	NA	20.1	2.56-2.64	Oxygen	300 W Xenon lamp, $\lambda > 420$ nm	6 h	Benzotrifluoride		0.1 MPa of O ₂	NA	Assynthesized photocatalyst: 25 mg, reaction volume (benzotrifluoride): 10 mL, benzyl alcohol: 1 mL	0.037	1.48	[47]
MIL-125(Ti)			7.5	3.71									0.013	0.52	
CdS			9.2										0.016	0.64	
TiO ₂ -MAGSNC	Wet impregnation	90	50	E _{P25} :3.15 E _{TiO2-MAGSNC} : 1.78 eV E _{MAGSNC} : 1.75 eV	Air	125 W lamp	4 h	Acetonitrile	30 °C	NA	SBET _{P25} : 59 m ² g ⁻¹ SBET _{TiO2-MAGSNC} : 292 m ² g ⁻¹ SBET _{MAGSNC} : 423 m ² g ⁻¹	Initial benzyl alcohol concentration (C ₀): 1.5 mM, reaction volume: 150 mL, catalyst loading: 150 mg, air flow rate: 25 mL min ⁻¹	0.17	1.13	[48]
2 wt% Au/HT-3	Co-precipitation	93.82/ 91.47	57.41/ 4.78	NA	Oxygen	LED lamp / dark	24 h	Benzotrifluoride	313 K	1 atm of O ₂	NA	Reaction volume (benzotrifluoride):10 mL, benzyl alcohol: 2 mmol, catalyst: 50 mg. The light intensity between 400 and 800 nm is 1.70 W cm ⁻²	0.035/ 0.002	0.7/ 0.04	[49]

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
0.05TiO ₂ -MAGSNC	Hydrothermal	84	20	E _{P25} :3.21 E _{TiO2-MAGSNC} : 1.62-1.67 eV E _{MAGSNC} 1.75 eV	Air	125 W lamp	4 h	Acetonitrile	30 °C	Atmospheric	SBET _{P25} : 59 m ² g ⁻¹ SBET _{TiO2-MAGSNC} : 400–500 m ² g ⁻¹	Initial benzyl alcohol concentration (C ₀): 1.5 mM, loading: 150 mg (1 g/L), air flow: 25 mL min ⁻¹	0.055	0.37	[50]
Fe ₂ O ₃ /g-C ₃ N ₄	One-pot mechanochemical	70	20	1.3	Air bubbling	UV light	4h	Acetonitrile	30 °C	NA	27 m ² g ⁻¹	Catalyst: 150 mg, benzyl alcohol: 1.5 mM, reaction volume (mother solution): 150 mL	0.056	0.37	[51]
CoSBA-15		63.8	7.97	NA	Air		24 h	CH ₃ CN	80 C		520 m ² g ⁻¹	Substrate/catalyst (wt): ~ 26, oxidant/substrate (mol): 4.4, oxidant/cobalt (mol): ~ 5200, catalyst: 10 mg, reaction volume (acetonitrile): 2mL	0.0035	0.35	[52]
TiO ₂	Wet impregnation and chemical	50	0.2	NA	Oxygen	UV and visible	6 h	Solvent-free	333 °K	NA	NA	Catalyst: 0.3 g, benzyl alcohol: 0.3 mol	0.00033	0.0011	[53]
Ag/TiO ₂		81	2.4										0.004	0.013	
Au/TiO ₂		81	6.4										0.011	0.037	
Pt/TiO ₂		79	3.3										0.006	0.02	
Pd/TiO ₂		81	4.1										0.007	0.023	
Rh/TiO ₂		83	8.7										0.015	0.05	
Ir/TiO ₂		92	8.9										0.015	0.05	
Pd-Ir/TiO ₂		82	25.6										0.049	0.16	

Catalyst/strategy		Selectivity (%)	Conversion (%)	Band gap (eV)	Oxidant	Radiant	Time	Solvent	Temp	Pressure	Surface area	Other	Pseudo first order rate constant (h ⁻¹)	Specific rate constant (g ⁻¹ h ⁻¹)	References
TiO ₂ /Cu(II)		63.4	84.07	NA	Air or oxygen	Solar radiation	385 min	NA	38.6 °C	NA	P25 Degussa TiO ₂ (80% anatase, 20% rutile): 50 m ² g ⁻¹ , TiO ₂ Aldrich (pure anatase phase): 9.5 m ² g ⁻¹ , photon energy of hv= 1486.74 eV	Accumulated energy value (Q _n): 78.9 kJ/l. [BA] ₀ : 1.5 mM. [Cu ^{II}] ₀ : 0.5 mM. Initial TiO ₂ (Aldrich) load: 200 mg L ⁻¹	0.29		[54]
Au/TiO ₂		63.9	15.3	NA											
Au-Pd/TiO ₂		91.6	74.5	NA											
Pd/TiO ₂		54.4	60.1	NA											
Zr-MOF	UiO-66-NH ₂ -H	>99	11.7	2.75	Oxygen	Dark	8 h	Solvent-free	373 °K	0.2 MPa of O ₂	885 m ² g ⁻¹	Benzyl alcohol: 26 µL, 0.25 mmol, Mesitylene: 0.1 mmol, 13.91 µL, reaction volume (toluene): 3 mL, catalyst: 0.1 mmol	0.005		[56]
	UiO-66-NH ₂ -F	>99	53.9	2.75							871 m ² g ⁻¹		0.032		
	UiO-66-NH ₂ -Cl	>99	38.2	2.75							798 m ² g ⁻¹		0.02		
	UiO-66-NH ₂ -Br	>99	43.4	2.75							689 m ² g ⁻¹		0.024		

References:

- Chen Z, Xu J, Ren Z, et al (2013) High efficient photocatalytic selective oxidation of benzyl alcohol to benzaldehyde by solvothermal-synthesized ZnIn₂S₄ microspheres under visible light irradiation. *J Solid State Chem* 205:134–141. <https://doi.org/10.1016/j.jssc.2013.07.015>
- Chen Z, Xu J, Ren Z, et al (2013) Low temperature synthesis of ZnIn₂S₄ microspheres as a visible light photocatalyst for selective oxidation. *Catal Commun* 41:83–86. <https://doi.org/10.1016/j.catcom.2013.07.016>
- Chen Z, Wu Y, Xu J, et al (2015) Synthesis of C-coated ZnIn₂S₄ nanocomposites with enhanced visible light photocatalytic selective oxidation activity. *J Mol Catal A Chem* 401:66–72. <https://doi.org/10.1016/j.molcata.2015.02.020>
- Chen Y, Wang Y, Li W, et al (2017) Enhancement of photocatalytic performance with the use of noble-metal-decorated TiO₂ nanocrystals as highly active catalysts for aerobic oxidation under visible-light irradiation. *Appl Catal B Environ* 210:352–367. <https://doi.org/10.1016/j.apcatb.2017.03.077>
- Tian J, Hu X, Wei N, et al (2016) RuO₂/TiO₂ nanobelt heterostructures with enhanced photocatalytic activity and gas-phase selective oxidation of benzyl alcohol. *Sol Energy Mater Sol Cells* 151:7–13. <https://doi.org/10.1016/j.solmat.2016.02.017>
- Zhang K, Liu Y, Deng J, et al (2019) Ru Nanoparticles Supported on Oxygen-Deficient 3DOM BiVO₄: High-Performance Catalysts for the Visible-Light-Driven Selective Oxidation of Benzyl Alcohol. *ChemCatChem* 11:6398–6407. <https://doi.org/10.1002/cctc.201901540>
- Zhang B, Li J, Gao Y, et al (2017) To boost photocatalytic activity in selective oxidation of alcohols on ultrathin Bi₂MoO₆ nanoplates with Pt nanoparticles as cocatalyst. *J Catal* 345:96–103. <https://doi.org/10.1016/j.jcat.2016.11.023>
- She H, Zhou H, Li L, et al (2018) Nickel-Doped Excess Oxygen Defect Titanium Dioxide for Efficient Selective Photocatalytic Oxidation of Benzyl Alcohol. *ACS Sustain Chem Eng* 6:11939–11948. <https://doi.org/10.1021/acssuschemeng.8b02217>
- Tzirakis MD, Lykakis IN, Panagiotou GD, et al (2007) Decatungstate catalyst supported on silica and γ -alumina: Efficient photocatalytic oxidation of benzyl alcohols. *J Catal* 252:178–189. <https://doi.org/10.1016/j.jcat.2007.09.023>
- Tsukamoto D, Ikeda M, Shiraishi Y, et al (2011) Selective photocatalytic oxidation of alcohols to aldehydes in water by TiO₂ partially coated with WO₃. *Chem - A Eur J* 17:9816–9824. <https://doi.org/10.1002/chem.201100166>
- Zhang Z, Luo Z, Yang Z, et al (2013) Band-gap tuning of N-doped TiO₂ photocatalysts for visible-light-driven selective oxidation of alcohols to aldehydes in water. *RSC Adv* 3:7215–7218. <https://doi.org/10.1039/c3ra40518d>
- Zhang Y, Xu YJ (2014) Bi₂WO₆: A highly chemoselective visible light photocatalyst toward aerobic oxidation of benzylic alcohols in water. *RSC Adv* 4:2904–2910. <https://doi.org/10.1039/c3ra46383d>
- Tong J, Zhang Q, Bo L, et al (2015) Effectively photocatalytic aerobic oxidation of benzyl alcohol catalyzed by spinel Co–Ni ferrite under visible light irradiation. *J Sol-Gel Sci Technol* 76:19–26. <https://doi.org/10.1007/s10971-015-3745-x>
- Zhang P, Liu Y, Tian B, et al (2017) Synthesis of core-shell structured CdS@CeO₂ and CdS@TiO₂ composites and comparison of their photocatalytic activities for the selective oxidation of benzyl alcohol to benzaldehyde. *Catal Today* 281:181–188. <https://doi.org/10.1016/j.cattod.2016.05.042>
- Xiao X, Jiang J, Zhang L (2013) Selective oxidation of benzyl alcohol into benzaldehyde over semiconductors under visible light: The case of Bi₁₂O₁₇Cl₂ nanobelts. *Appl Catal B Environ* 142–143:487–493. <https://doi.org/10.1016/j.apcatb.2013.05.047>
- Schünemann S, Gastel M van, Tüysüz H (2018) A cspbbr3/tio2 composite for visible-light-driven photocatalytic benzyl alcohol oxidation. *ChemSusChem* 11:1, 2057–2061. <https://doi.org/10.1002/cssc.201800679>
- Tian J, Li J, Wei N, et al (2016) Ru nanoparticles decorated TiO₂ nanobelts: A heterostructure towards enhanced photocatalytic activity and gas-phase selective oxidation of benzyl alcohol. *Ceram Int* 42:1611–1617. <https://doi.org/10.1016/j.ceramint.2015.09.112>
- Shen L, Liang S, Wu W, et al (2013) CdS-decorated UiO-66(NH₂) nanocomposites fabricated by a facile photodeposition process: An efficient and stable visible-light-driven photocatalyst for selective oxidation of alcohols. *J Mater Chem A* 1:11473–11482. <https://doi.org/10.1039/c3ta12645e>
- Zhang N, Fu X, Xu YJ (2011) A facile and green approach to synthesize Pt@CeO₂ nanocomposite with tunable core-shell and yolk-shell structure and its application as a visible light photocatalyst. *J Mater Chem* 21:8152–8158. <https://doi.org/10.1039/c1jm10100e>

20. Zhang M, Chen C, Ma W, Zhao J (2008) Visible-light-induced aerobic oxidation of alcohols in a coupled photocatalytic system of dye-sensitized TiO₂ and TEMPO. *Angew Chemie - Int Ed* 47:9730–9733. <https://doi.org/10.1002/anie.200803630>
21. Ke F, Wang L, Zhu J (2015) Facile fabrication of CdS-metal-organic framework nanocomposites with enhanced visible-light photocatalytic activity for organic transformation. *Nano Res* 8:1834–1846. <https://doi.org/10.1007/s12274-014-0690-x>
22. Li H, Qin F, Yang Z, et al (2017) New Reaction Pathway Induced by Plasmon for Selective Benzyl Alcohol Oxidation on BiOCl Possessing Oxygen Vacancies. *J Am Chem Soc* 139:3513–3521. <https://doi.org/10.1021/jacs.6b12850>
23. Xiao X, Zheng C, Lu M, et al (2018) Deficient Bi₂₄O₃₁Br₁₀ as a highly efficient photocatalyst for selective oxidation of benzyl alcohol into benzaldehyde under blue LED irradiation. *Appl Catal B Environ* 228:142–151. <https://doi.org/10.1016/j.apcatb.2018.01.076>
24. Jing K, Ma W, Ren Y, et al (2019) Hierarchical Bi₂MoO₆ spheres in situ assembled by monolayer nanosheets toward photocatalytic selective oxidation of benzyl alcohol. *Appl Catal B Environ* 243:10–18. <https://doi.org/10.1016/j.apcatb.2018.10.027>
25. Zou J, Wang Z, Guo W, et al (2020) Photocatalytic selective oxidation of benzyl alcohol over ZnTi-LDH: The effect of surface OH groups. *Appl Catal B Environ* 260:118185. <https://doi.org/10.1016/j.apcatb.2019.118185>
26. Song H, Liu Z, Wang Y, et al (2019) Template-free synthesis of hollow TiO₂ nanospheres supported Pt for selective photocatalytic oxidation of benzyl alcohol to benzaldehyde. *Green Energy Environ* 4:278–286. <https://doi.org/10.1016/j.gee.2018.09.001>
27. Zhang P, Wu P, Bao S, et al (2016) Synthesis of sandwich-structured AgBr@Ag@TiO₂ composite photocatalyst and study of its photocatalytic performance for the oxidation of benzyl alcohols to benzaldehydes. *Chem Eng J* 306:1151–1161. <https://doi.org/10.1016/j.cej.2016.08.015>
28. Du M, Zeng G, Ye C, et al (2020) Solvent-free photo-thermocatalytic oxidation of benzyl alcohol on Pd/TiO₂ (B) nanowires. *Mol Catal* 483:110771. <https://doi.org/10.1016/j.mcat.2020.110771>
29. Du M, Zeng G, Huang J, et al (2019) Green Photocatalytic Oxidation of Benzyl Alcohol over Noble-Metal-Modified H₂Ti₃O₇ Nanowires. *ACS Sustain Chem Eng* 7:9717–9726. <https://doi.org/10.1021/acssuschemeng.9b01817>
30. Wang F, Gu Y, Yang Z, et al (2018) The effect of halogen on BiOX (X = Cl, Br, I)/Bi₂WO₆ heterojunction for visible-light-driven photocatalytic benzyl alcohol selective oxidation. *Appl Catal A Gen* 567:65–72. <https://doi.org/10.1016/j.apcata.2018.09.010>
31. Liu Y, Zhang P, Tian B, Zhang J (2015) Core-Shell Structural CdS@SnO₂ Nanorods with Excellent Visible-Light Photocatalytic Activity for the Selective Oxidation of Benzyl Alcohol to Benzaldehyde. *ACS Appl Mater Interfaces* 7:13849–13858. <https://doi.org/10.1021/acsami.5b04128>
32. Ma J, Yu X, Liu X, et al (2019) The preparation and photocatalytic activity of Ag-Pd/g-C₃N₄ for the coupling reaction between benzyl alcohol and aniline. *Mol Catal* 476:110533. <https://doi.org/10.1016/j.mcat.2019.110533>
33. Shen L, Liang S, Wu W, et al (2013) Multifunctional NH₂-mediated zirconium metal-organic framework as an efficient visible-light-driven photocatalyst for selective oxidation of alcohols and reduction of aqueous Cr(vi). *Dalt Trans* 42:13649–13657. <https://doi.org/10.1039/c3dt51479j>
34. Kitano S, Tanaka A, Hashimoto K, Kominami H (2014) Selective oxidation of alcohols in aqueous suspensions of rhodium ion-modified TiO₂ photocatalysts under irradiation of visible light. *Phys Chem Chem Phys* 16:12554–12559. <https://doi.org/10.1039/c4cp00863d>
35. Zhang XF, Wang Z, Zhong Y, et al (2019) TiO₂ nanorods loaded with Au–Pt alloy nanoparticles for the photocatalytic oxidation of benzyl alcohol. *J Phys Chem Solids* 126:27–32. <https://doi.org/10.1016/j.jpcs.2018.10.026>
36. Xu J, Luo L, Xiao G, et al (2014) Layered C₃N₃S₃ polymer/graphene hybrids as metal-free catalysts for selective photocatalytic oxidation of benzylic alcohols under visible light. *ACS Catal* 4:3302–3306. <https://doi.org/10.1021/cs5006597>
37. Xue J, Li X, Ma S, et al (2019) Facile fabrication of BiOCl/RGO/protonated g-C₃N₄ ternary nanocomposite as Z-scheme photocatalyst for tetracycline degradation and benzyl alcohol oxidation. *J Mater Sci* 54:1275–1290. <https://doi.org/10.1007/s10853-018-2880-5>
38. Chen BB, Ma DK, Ke QP, et al (2016) Indented Cu₂MoS₄ nanosheets with enhanced electrocatalytic and photocatalytic activities realized through edge engineering. *Phys Chem Chem Phys* 18:6713–6721. <https://doi.org/10.1039/c5cp07900d>
39. Bi J, Zhou Z, Chen M, et al (2015) Plasmonic Au/CdMoO₄ photocatalyst: Influence of surface plasmon resonance for selective photocatalytic oxidation of benzylic

alcohol. *Appl Surf Sci* 349:292–298. <https://doi.org/10.1016/j.apsusc.2015.04.213>

40. Zhang N, Liu S, Fu X, Xu YJ (2011) A simple strategy for fabrication of “plum-pudding” type Pd@CeO₂ semiconductor nanocomposite as a visible-light-driven photocatalyst for selective oxidation. *J Phys Chem C* 115:22901–22909. <https://doi.org/10.1021/jp205821b>
41. Magdziarz A, Colmenares JC, Chernyayeva O, et al (2017) Insight into the synthesis procedure of Fe³⁺/TiO₂-based photocatalyst applied in the selective photo-oxidation of benzyl alcohol under sun-imitating lamp. *Ultrason Sonochem* 38:189–196. <https://doi.org/10.1016/j.ultsonch.2017.03.012>
42. Xu C, Qian L, Lin J, et al (2019) Heptazine-based porous polymer for selective CO₂ sorption and visible light photocatalytic oxidation of benzyl alcohol. *Microporous Mesoporous Mater* 282:9–14. <https://doi.org/10.1016/j.micromeso.2019.03.011>
43. Dai X, Xie M, Meng S, et al (2014) Coupled systems for selective oxidation of aromatic alcohols to aldehydes and reduction of nitrobenzene into aniline using CdS/g-C₃N₄ photocatalyst under visible light irradiation. *Appl Catal B Environ* 158–159:382–390. <https://doi.org/10.1016/j.apcatb.2014.04.035>
44. Ye X, Dai X, Meng S, et al (2017) A Novel CdS/g-C₃N₄ Composite Photocatalyst: Preparation, Characterization and Photocatalytic Performance with Different Reaction Solvents under Visible Light Irradiation. *Chinese J Chem* 35:217–225. <https://doi.org/10.1002/cjoc.201600251>
45. Xie M, Dai X, Meng S, et al (2014) Selective oxidation of aromatic alcohols to corresponding aromatic aldehydes using In₂S₃ microsphere catalyst under visible light irradiation. *Chem Eng J* 245:107–116. <https://doi.org/10.1016/j.cej.2014.02.029>
46. Wu Z, Huang X, Zheng H, et al (2018) Aromatic heterocycle-grafted NH₂-MIL-125(Ti) via conjugated linker with enhanced photocatalytic activity for selective oxidation of alcohols under visible light. *Appl Catal B Environ* 224:479–487. <https://doi.org/10.1016/j.apcatb.2017.10.034>
47. Zhang R, Li G, Zhang Y (2017) Photochemical synthesis of CdS-MIL-125(Ti) with enhanced visible light photocatalytic performance for the selective oxidation of benzyl alcohol to benzaldehyde. *Photochem Photobiol Sci* 16:996–1002. <https://doi.org/10.1039/c7pp00073a>
48. Colmenares JC, Ouyang W, Ojeda M, et al (2016) Mild ultrasound-assisted synthesis of TiO₂ supported on magnetic nanocomposites for selective photo-oxidation of benzyl alcohol. *Appl Catal B Environ* 183:107–112. <https://doi.org/10.1016/j.apcatb.2015.10.034>
49. Yu J, Li J, Wei H, et al (2014) Hydrotalcite-supported gold catalysts for a selective aerobic oxidation of benzyl alcohol driven by visible light. *J Mol Catal A Chem* 395:128–136. <https://doi.org/10.1016/j.molcata.2014.08.023>
50. Ouyang W, Kuna E, Yezpez A, et al (2016) Mechanochemical synthesis of TiO₂ nanocomposites as photocatalysts for benzyl alcohol photo-oxidation. *Nanomaterials* 6:1–12. <https://doi.org/10.3390/nano6050093>
51. Cerdan K, Ouyang W, Colmenares JC, et al (2019) Facile mechanochemical modification of g-C₃N₄ for selective photo-oxidation of benzyl alcohol. *Chem Eng Sci* 194:78–84. <https://doi.org/10.1016/j.ces.2018.04.001>
52. Brutchey RL, Drake IJ, Bell AT, Tilley TD (2005) Liquid-phase oxidation of alkylaromatics by a H-atom transfer mechanism with a new heterogeneous CoSBA-15 catalyst. *Chem Commun* 1:3736–3738. <https://doi.org/10.1039/b506426k>
53. Feng W, Wu G, Li L, Guan N (2011) Solvent-free selective photocatalytic oxidation of benzyl alcohol over modified TiO₂. *Green Chem* 13:3265–3272. <https://doi.org/10.1039/c1gc15595d>
54. Spasiano D, Del Pilar Prieto Rodriguez L, Olleros JC, et al (2013) TiO₂/Cu(II) photocatalytic production of benzaldehyde from benzyl alcohol in solar pilot plant reactor. *Appl Catal B Environ* 136–137:56–63. <https://doi.org/10.1016/j.apcatb.2013.01.055>
55. Enache DI, Edwards JK, Landon P, et al (2006) Solvent-free oxidation of primary alcohols to aldehydes using Au-Pd/TiO₂ catalyst. *Science* (80-) 311:362–365. <https://doi.org/10.1126/science.1120560>
56. Goh TW, Xiao C, Maligal-Ganesh R V., et al (2015) Utilizing mixed-linker zirconium based metal-organic frameworks to enhance the visible light photocatalytic oxidation of alcohol. *Chem Eng Sci* 124:45–51. <https://doi.org/10.1016/j.ces.2014.08.052>