Supplementary Information

Recent Advances in Bismuth Oxyhalide Photocatalysts for Degradation of Organic Pollutants in Wastewater

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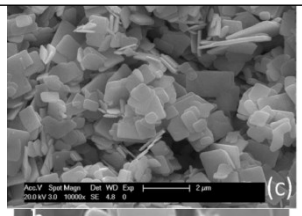
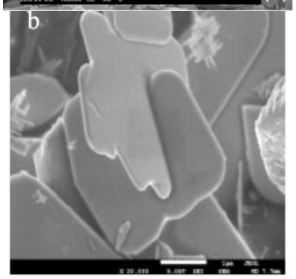
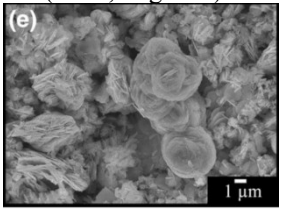
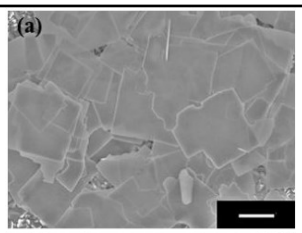
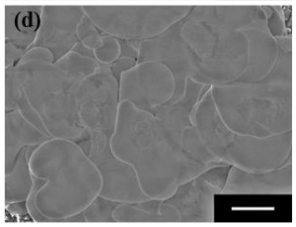
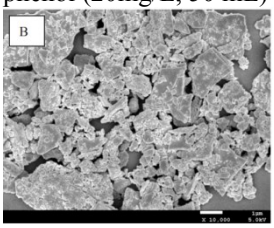
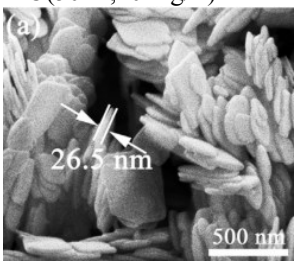
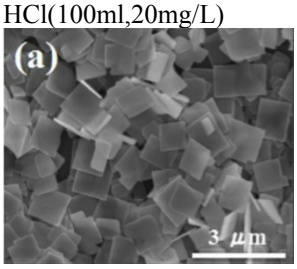
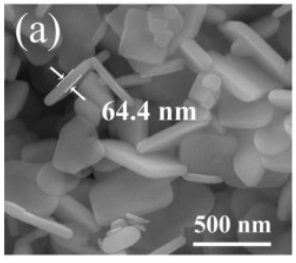
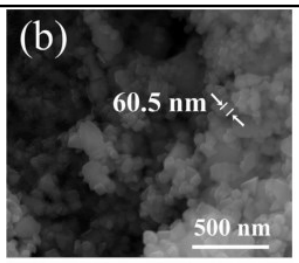
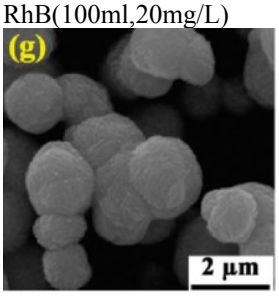
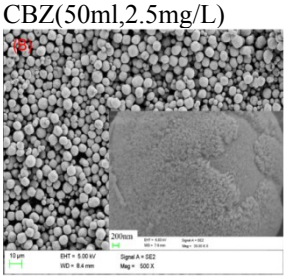
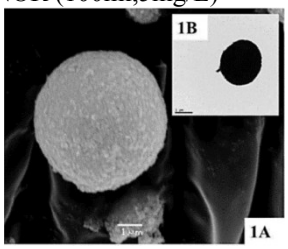
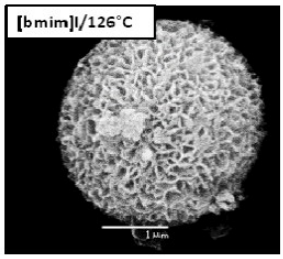
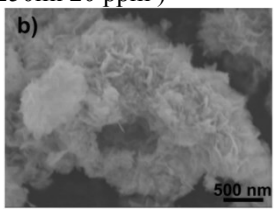
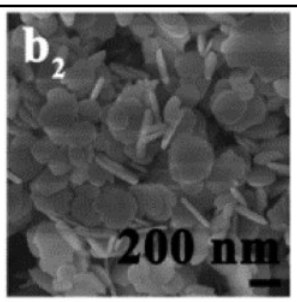
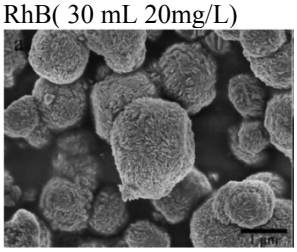
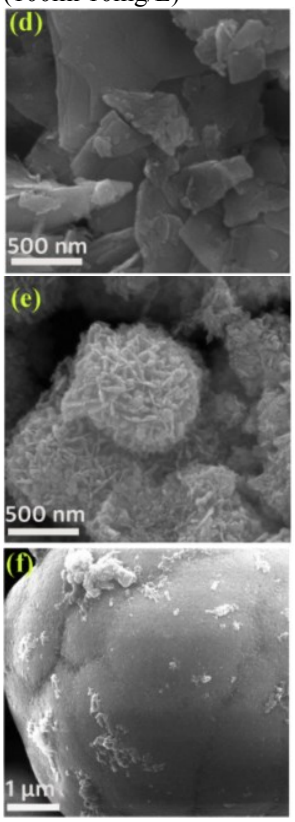
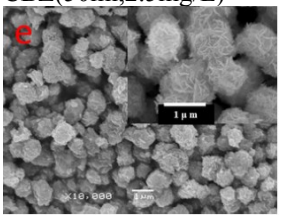
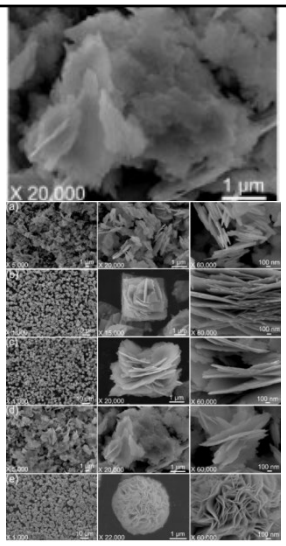
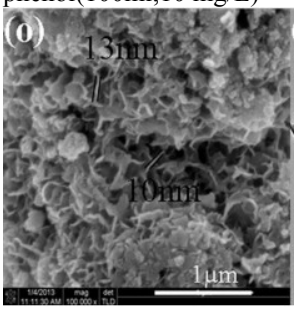
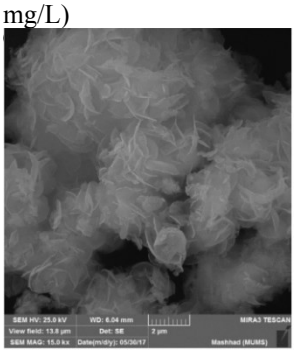
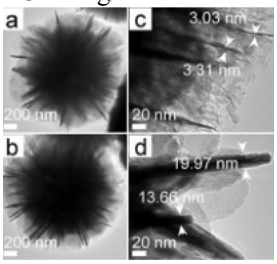
Table S1 Controllable ynthesis of BiOX photocatalysts and their photodegradation performance

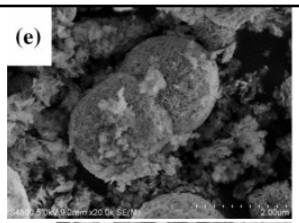
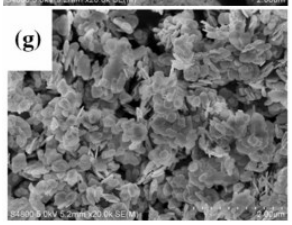
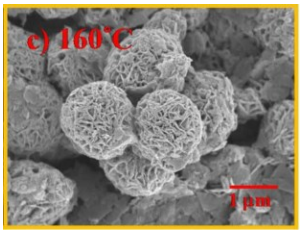
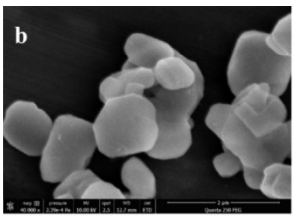
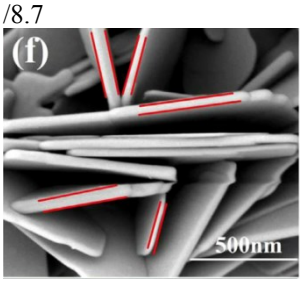
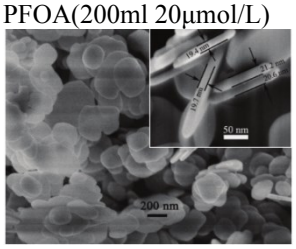
Material/method	Morphology/Dye/concentration	Light	Degradation performance	Refer
BiOCl hydrothermal method; $Bi(NO_3)_3 \cdot 5H_2O$,ultra-water,NaCl, NaOH , pH=2/7/10, 160°C24h	 0.02g BiOBr CIP(40ml,5mg L−1)	UV lamp	BiOCl-10>BiOCl-7>BiOCl-2 efficiency of oxidation gaseous Hg Degradation rate: Hg 2500s 60%	[3]
BiOBr hydrothermal approach $NaBiO_3 \cdot 2H_2O$,HNO_3,deionisedwater, 200°C for 24 h	 0.2g BiOBr RhB (200ml,1×10-5M)	400W halogen lamp	K(pH=9)=0.037	[4]
BiOBr hydrothermal Method; $Bi(NO_3)_3 \cdot 5H_2O$, NaBr, water pH=2-10, 180°C for 20h	 0.2g BiOBr RhB (200ml,1×10-5M)	Xe lamp	BiOBr-8>BiOBr-6>BiOBr-4>BiOBr-10>BiOBr-2. Degradation rate： RhB 45min 99%	[5]

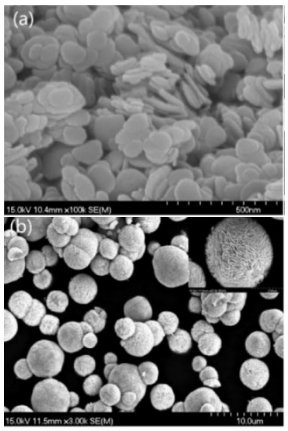
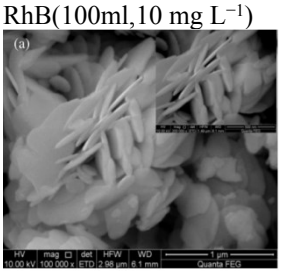
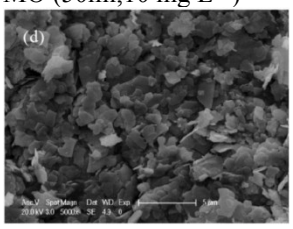
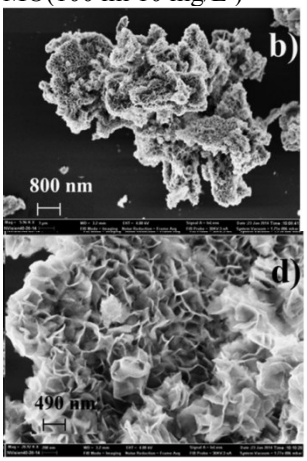
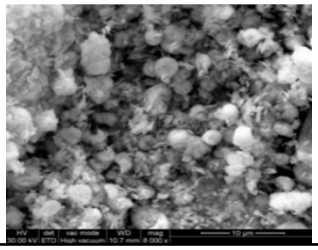
BiOBr-1 2 3 4 hydrothermal method; $Bi(NO_3)_3 \cdot 5H_2O$, CTAB, NaOH(adjust pH=7 5 3 2)170°C for 17h (a) BiOBr-squareBiOBr-1 (b) BiOBr-circle BiOBr-4	  0.1g BiOBr RhB(0.02mmol/L,100mL) 0.05g BiOBr MO(50ml,10 mg/L) 0.5g BiOBr phenol (20mg/L, 50 mL)	300W Xe lamp	Degradation rate RhB MO phenol BiOBr-circle>BiOBr-square> N doped P25 Degradation rate： RhB 30min 100%	[6]
BiOI hydrothermal approach; $Bi(NO_3)_3 \cdot 5H_2O$, KI, F127, glacial acetic acid; 180°C 24h and 300° 2h	 1g/L BiOI MO(50ml,10 mg/L)	500W Xe lamp	F127-BiOI>BiOI KF127-BiOI=0.229 kBiOI=0.108	[7]
BiOCl hydrothermalmethod; $Bi(NO_3)_3 \cdot 5H_2O$, dulcitol, KCl, HNO_3/ KOH adjusted pH=4/6/8/10 160°C 24h	 50 mg BiOCl RhB/TC-HCl(100ml,20mg/L)	visible light	BiOCl-4>BiOCl-6>BiOCl-8>BiOCl-10 Degradation rate: RhB 6 min more than 98% Degradation rate: TC-HCl 90 min 60%	[8]
BiOCl hydrothermal route; $Bi(NO_3)_3 \cdot 5H_2O$, HNO_3, C-PAM, SodiumCitrate, 0.3g NaOH, 150°C4h	 50 mg T-BiOCl MO(50ml,20mg/L)	300W mercury lamp	BiOCl-150°>BiOCl-180°>BiOCl-120° BiOCl-12h>BiOCl-4h>BiOCl-2h>BiOCl-1h BiOCl(1.2gNaOH)>BiOCl(0.9gNaOH)>BiOCl(0.6gNaOH)>BiOCl(0.3gNaOH)>BiOCl(0gNaOH) BiOCl>P25 K=0.0655	[9]
BiOCl hydrothermal route ; BOC-1 BOC-2 BOC-3 BOC-4 $Bi(NO_3)_3 \cdot 5H_2O$,deionizedwater, Xylitol(0.1g,0.3g,0.5g,1.0g),KCl, KOH,160°C24h (a)BOC-1 (b)BOC-4		visible light	BOC-1>BOC-3>BOC-1>BOC-2> BOC-4 Degradation rate: RhB 20min 98%	[10]

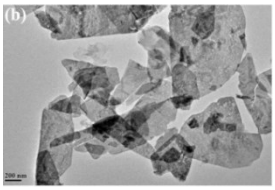
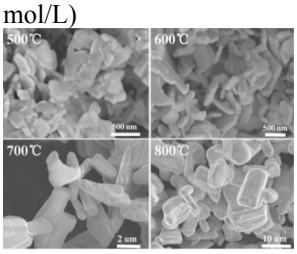
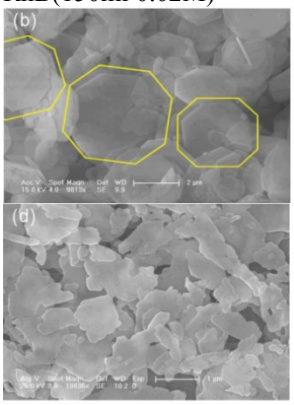
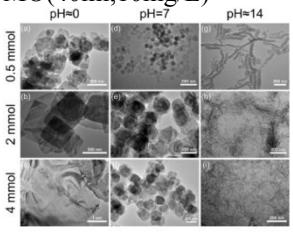
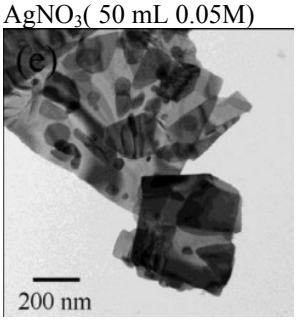
	 50 mg BiOCl RhB(100ml,20mg/L)			
BiOCl ethylene glycolmediated solvothermal method; BiOCl-1/5/10/15 $Bi(NO_3)_3 \cdot 5H_2O$,KCl(1/5/10/15),ethylene glycol,160°C 12h	 40 mg BiOCl CBZ(50ml,2.5mg/L)	300W xenon lamp	BiOCl-10>BiOCl-5>BiOCl-15>BiOCl-1 Degradation rate: CBZ 180min 70%	[11]
BiOCl-120/140/160/180; one-stepsolvothermal method; $Bi(NO_3)_3$,ethyleneglycol,HCl; 120/140/160/180°C 24h BiOCl-140-400; BiOCl-140,400°C 2h	 50 mg BiOCl NOR (100ml,5mg/L)	300W xenon lamp	BiOCl-140>BiOCl-120>BiOCl-160>BiOCl-180>BiOCl-140-400 Degradation rate: NOR 120min 57.8%	[12]
BiOBr microspheres solvothermal synthesis; $Bi(NO_3)_3 \cdot 5H_2O$,KBr,ethylene glycol; 145°C18h	 0.08g BiOBr MO (200ml,10 mg L^{-1})	12W xenon lamp	BiOBr>BiOBr(with HA_C) BiOBr(pH=2)>BiOBr(pH=other) Degradation rate： MO 60min 97%	[13]
BiOI solvothermal method; $Bi(NO_3)_3 \cdot 5H_2O$,KI ,ethylene glycol;120-216.6°C12-24.5h, $Bi(NO_3)_3 \cdot 5H_2O$, ionic liquid 1- 5 butyl-3-metilimidazolium iodide,ethylene glycol;120-216.6°C12-24.5h	 0.025 g BiOI gallic acid solution (250ml 20 ppm)	12W xenon lamp	[bmim]I>KI(126°18h)>other Degradation rate: gallic acid 60 min 61%	[14]
BiOI：hollow flower solvothermal method; $Bi(NO_3)_3 \cdot 5H_2O$,KI ,ethylene glycol; 160°C24h	 100 mg BiOI RhB(20 mg L^{-1})	350W Xe arclamp	hollow flowerBiOI>bulk BiOI Degradation rate ： 60min 99.6% RhB	[15]

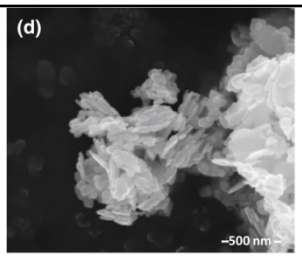
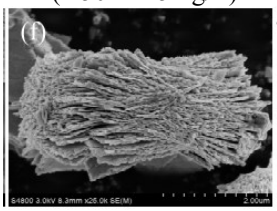
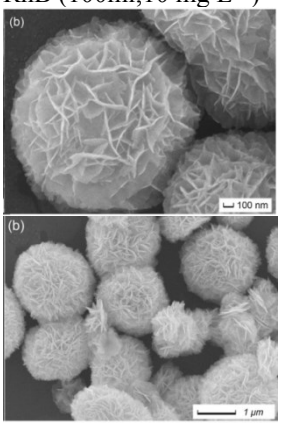
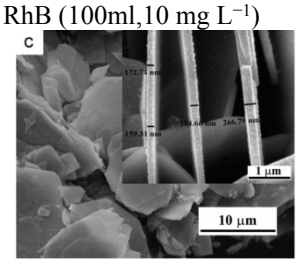
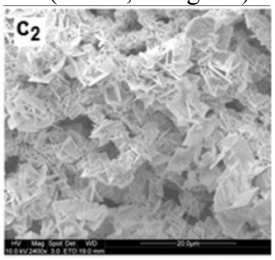
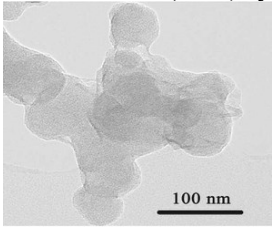
$BiOBrxI_{1-x}$ solvothermal method; $Bi(NO_3)_3{\cdot}5H_2O$,NH_4Br,NH_4I,ethylene glycol;160 °C for 12 h	 10.0 mg $BiOBr_xI_{1-x}$ RhB(30 mL 20mg/L)	350W Xe arc lamp	$BiOBr_xI_{1-x}$(x=0.8)>$BiOBr_xI_{1-x}$(x=0.5) >$BiOBr_xI_{1-x}$(x=1)>$BiOBr_xI_{1-x}$(x=0.2) >$BiOBr_xI_{1-x}$(x=0)>P25 Degradation rate: RhB 90min 99%	[16]
BiOCl solvothermal modification method; OV-BOC $Bi(NO_3)_3{\cdot}5H_2O$,NaCl,EG,160°C,16 h BOC $Bi(NO_3)_3{\cdot}5H_2O$,NaCl,EtOH,160°C, 16h	 100 mg BiOCl RhB/MO/phenol (100ml 10mg/L)	300W xenon lamp	OV-BOC+H_2O_2>OV-BOC>BOC >H_2O_2	[17]
BiOCl alcohol mediated solvothermal method; $Bi(NO_3)_3{\cdot}5H_2O$,KCl,1-ethanol/ 2-ethylene glycol/3-glycerol; 160◦C,12h (d)BiOCl-1 (e)BiOCl-2 (f)BiOCl-3	 40 mg BiOCl CBZ(50ml,2.5mg/L)	350W xenon lamp	BiOCl-2>BiOCl-3>BiOCl-1 K=0.0118	[18]
BiOBr solvothermal route; $Bi(NO_3)_3{\cdot}5H_2O$,KBr,deionized water (ETH ,ISO ,EG , GLY)140°C 16h	 0.2g BiOBr Brilliantblue K-NR (100ml,30 mg L^{-1})	300W Xenon lamp	BiOBr(GLY)>BiOBr(EG)>BiOBr(ISO)>BiOBr(E)>BiOBr(W) Degradation rate： brilliant blue K-NR 120min 90.9%	[19]

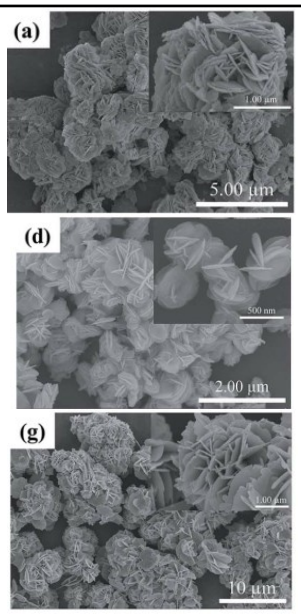
BiOBr solvothermal approach; $Bi(NO_3)_3{\cdot}5H_2O$,CTAB,ethanol, 150°C 24h (a)BiOBr-EtOH, (b)BiOBr-EG, (c)BiOBr-TB, (d)BiOBr-BA (e)BiOBr-ME	 0.025g BiOBr RhB (100ml,10 mg L^{-1}) 0.1g BiOBr phenol(100ml,10 mg/L)	300W Xenon lamp	BiOBr(BA)>BiOBr(ME)>BiOBr(TB) >BiOBr(EtOH)>BiOBr(EG)>BiOBr (W) Degradation rate： RhB K=0.148 Degradation rate： Phenol 3h almost 20%	[20]
BiOI hydrothermal or solvothermal method; $Bi(NO_3)_3{\cdot}5H_2O$,KI,H_2O, ETH, EG, GLY;160°C,12 h	 40 mg BiOI As(III)solution(80 mL 5 mg/L)	300W Xe lamp	GLY>EG>ETH Degradation rate: As(III) 40 min 96.6%	[21]
BiOI hydrolysismethod(BiOI-H) solvothermal method (BiOI-ST) ; BiOI-ST:$Bi(NO_3)_3{\cdot}5H_2O$,KI ,ethylen-e glycoldistillated water;180°C12h	 0.68g/L BiOI TCH 2mg/L	1000W tungstn halogenlam- p	BiOI-ST>BiOI-H Degradation rate: TCH:101.5 min 100%	[22]
BiOCl-1 solvothermal process $Bi(NO_3)_3{\cdot}5H_2O$,PEG10000,PEG400, NaCl,180°C24h BiOCl-2 $Bi(NO_3)_3{\cdot}5H_2O$,CTAB,PEG400,NaCl ,180°C15h BiOCl $Bi(NO_3)_3{\cdot}5H_2O$,mannitolsolution,Na Cl,160°3h (a)BiOCl-1 (b)BiOCl-2	 50 mg BiOCl BPA aqueous(50ml,1×10^{-5}m)	300W Hg arc lamp	BiOCl-1>BiOCl-2 Degradation rate: BPA 6h 96% Degradation rate: TOC 13h 96%	[23]

BiOCl facile solvothermal method; $Bi(NO_3)_3 \cdot 5H_2O$,KCl,methanol ,desired volume fractions of water (0, 5, 10, and 15%)120°C12h BOC-1 BOC-2 BOC-3 BOC-4 (e)BOC-1 (g)BOC-3	  10 mg BiOCl RhB(50ml,20mg/L) MO(50ml,10mg/L)	300W xenon lamp	BOC-3>BOC-1>BOC-2>BOC-4 Degradation rate: MO 50min almost 100% Degradation rate: RhB 40min almost 100%	[24]
BiOX microwave-assisted solvothermal method; $Bi(NO_3)_3 \cdot 5H_2O$,KX,EG,EtOH,PEG,microwave 450W(10 20 30 60min)(120 140 160°C)pH (3, 5, 7, and 9) BiOAxB1-x KAB	 BiOICatalysts 0.1g/L-0.4g/L 100ml deionized water	350W xenon light	hydrogen evolution rate BiOI Ph=7>Ph=5>Ph=9>Ph=3 Ph=7(1,316.9 μmol $h^{-1}g^{-1}$) catalyst dosage 0.2g/L>other 1316.9 μmol $h^{-1}g^{-1}$ Catalyst type BiOI>BiOBr, BiOCl BiOI>BiOAxB1-x	[25]
BiOCl hydrolysismethod; $NaBiO_3 \cdot 2H_2O$,deionized water,HCl,	 50mg/L 100mg/L 200mg/L 300mg/L 400mg/L BiOCl ATL (10μM) in 30 mL DI water 300mg/L BiOCl ATL (10μM) in 30 mL DI water PBSadjustedpH=5.2/6/7/8/8.7	500W xenon lamp	BiOCl(400mg/L)>BiOCl(300mg/L)>BiOCl(200mg/L)>BiOCl(100mg/L)>BiOCl(50mg/L) Degradation rate:BiOCl(300mg/L) ATL 60min 90% BiOCl(pH=5.2)>BiOCl(pH=6)>BiOCl(pH=7)>BiOCl(pH=8.7)>BiOCl(pH=8)	[26]
BiOCl hydrolytic method; bismuth nitrate,HCl,Sodium carbonate,pH=2	 100 mg BiOCl PFOA(200ml 20μmol/L)	UV Irradiation (254nm,10 W)	BiOCl>ln_2O_3>P25 defluorination efficiency : 24h,59.3%	[27]
BiOCl hydrolysis method; NaCl,$Bi(NO_3)_3 \cdot 5H_2O$, ethanol,NaCl ,90°C 3h	 40 mg BiOCl RhB(40ml,20mg/L)	500W xenon lamp	RhB> MO > MB . Degradation rate: MB 30min 94%	[28]

	MO/MB(40ml,10mg/L)			
BiOBr-1 a hydrolysis process; $Bi(NO_3)_3 \cdot 5H_2O$,KBr,EG,deionised water BiOBr-2 b solvothermal synthesis; $Bi(NO_3)_3 \cdot 5H_2O$,KBr,EG,160°C,10h	 0.02g BiOBr RhB(100ml,10 mg L^{-1})	300W xenon lamp	UV irradiation: RhB 120min 97% BiOBr-1>P25>BiOBr-2 vis-light irradiation: BiOBr-1>BiOBr-2>P25	[29]
BiOBr hydrolysis or alcoholysis method; $BiBr_3$,water(H_2O),ethanol,isopropyl alcohol,room temperature,magnetic stirring 20°C 40°C 60°C	 0.03g BiOBr MO (50ml,10 mg L^{-1})	350W Xenon lamp	BiOBr- 60(IPA)>BiOBr(H_2O))>BiOBr(EtOH) Degradation rate： BiOBr(IPA) MO 75min 98.9% BiOBr(H_2O) MO 75min 91.3%	[30]
BiOI hydrolysismethod; $Bi(NO_3)_3 \cdot 5H_2O$,KI,deionized water: 10-50ml,room temperature.	 0.05 g BiOI MO(100 ml 10 mg/L)	300W Xearc lamp	BiOI-40>BiOI-50>BiOI-30>BiOI-20 >BiOI-10 Degradation rate: MO 120 min 71.4%	[31]
BiOX(Cl/I) BiOCl /BiOI hydrolysis method $NaBiO_3$,ethanol,DI water,HCl/HI (b)BiOCl (d)BiOI	 BiOX(500mg/L) EE2and estriol	four 128W/m^2 254nmbulbs	Degradation rate: BiOI>BiOCl>TiO2 EE2 30min 100% Degradation rate: BiOCl>BiOI>TiO2 estriol 30min 100%	[32]
BiOX facile co-precipitation method, $Bi(NO_3)_3 \cdot 5H_2O$,NaBr solution, stirre 24 h low-temperature solutionroute, facile chemical etching method			$BiOI_{0.5}Br_{0.5}$> BiOI>BiOBr Degradation rate: Lindane120min 95%	[33]

Br-BiOI chemical precipitation route; $Bi(NO_3)_3{\cdot}5H_2O$,KI,NaBr, ethylene glycol;room temperature	 50 mg Br-BiOI RhB;phenol(50mL of $3*10^{-5}$ mol/L)	500W Xe lamp visible light	15% Br-BiOI>20% Br-BiOI>10% Br-BiOI>5% Br-BiOI> BiOI Degradation rate : 15% Br-BiOI ;2.5h RhB almost 100% 15% Br-BiOI; 10h phenol more than 50%	[34]
$Bi_{24}O_{31}Cl_{10}$ chemicalprecipitation method; $Bi(NO_3)_3{\cdot}5H_2O$,HNO_3,CTAC,NaOH, 400°C-800°C	 100 mg BiOCl RhB(150ml 0.02M)	500W xenon lamp	$Bi_{24}O_{31}Cl_{10}$>BiOCl>TiO_2/N>Bi_2O_3 Degradation rate: RhB 60min 95%	[35]
BiOCl two-phase reaction;BiOCl-1 octagonal: $Bi(NO_3)_3{\cdot}5H_2O$,HCl,deionized water BiOCl-2 $Bi(NO_3)_3{\cdot}5H_2O$,KCl,deionized water (b)BiOCl-1 (d)BiOCl-2	 40 mg BiOCl MO(40ml,10mg/L)	500W xenon lamp	BiOCl-1>BiOCl-2 Degradation rate: MO 80min almost 100%	[36]
BiOX two-phase method; BIOCl/Br-NSS $Bi(NO_3)_3{\cdot}5H_2O$, ODE,OA,OLA,N_2,170°C,KBr/I/Cl, HNO_3,100°C,0.5h	 25mg BIOBr RhB/MB(100 mL 10mg/L) O_2evolution 25mg BIOBr $AgNO_3$(50 mL 0.05M)	300W xenon lamp	BiOBr-acid0.5>BiOBr-neutral0.5>BiOBr-acid4 Degradation rate: RhB 50min 96% Degradation rate: MO 120min 39% O_2evolution BiOBr-acid4 best	[37]
BiOI nanoplates sonochemical method; $Bi(NO_3)_3{\cdot}6H_2O$,NaI,deionized water,NaOH; 35kHz ultrasonic bath at 80°C 5h.	 200 mgBiOI RhB(200ml 1×10^{-5}M)	Xe lamp	pH=12>pH=10>pH=8 Degradation rate: RhB 180min 81.19%	[38]

BiOI microwave method $Bi(NO_3)_3{\cdot}5H_2O$, acetic acid, EDTA, KI, 110℃, 5min	 250 mgBiOI RhB(250 mL 5mg/L)	6000K Xenon lamp	B110-40>B130-40>B110-40>B150-40>B110-20>B110-00 Degradation rate: RhB 20min 98.2%	[39]
BiOBr microwave-assisted ionothermal synthesis; $Bi(NO_3)_3{\cdot}5H_2O$,HB (OB,HK,CTAB,MI), EG, 1000W, 160°C/400°C 4h	 0.025g BiOBr RhB (100ml,10 mg L^{-1})	300W Xenon lamp	BiOBr>BiOBr(THB)>BiOBr(BQ)>BiOBr(EDTA)>BiOBr($AgNO_3$) Degradation rate： RhB 180min 99.57% TOC 180min 12.24%	[40]
BiOBr porous nanospheres microwave-assisted ionic liquid Synthsis; $Bi(NO_3)_3{\cdot}5H_2O$, PVP K30, EG, [C16mim]Br, microwave reactor 160°C 20min BiOBr hollow microspheres(without pvp)	 0.02g BiOBr RhB (100ml,10 mg L^{-1})	300W Xenon lamp	Porous BiOBr>Hollow BiOBr Degradation rate： RhB 60min almost 100%	[41]
BiOBr combustion method; $Bi(NO_3)_3{\cdot}5H_2O$, NH_4Br, urea, nitric acid, deionized water; 300°C	 0.1g BiOBr RhB(100ml,20 mg L^{-1})	300W xenon lamp	NH_4Br/ $Bi(NO_3)_3{\cdot}5H_2O$(3 4, and 5) BiOBr-5>BiOBr-4>BiOBr-3 Degradation rate： RhB 120min 91.6%	[42]
BiOBr electrospinning and postcalcination $BiBr_3$ 500°C $BiBr_3$(as1%,2%, 3% and 4%) in polymer (PAN)	 Alizarin Red S (ARS) dye	150W Xe lamp	BiOBr(X=4)>BiOBr(X=1)>BiOBr(X=3)>BiOBr(X=2)	[43]
BiOBr nanosheets Liquid Phase Exfoliation $Bi(NO_3)_3{\cdot}5H_2O$, KBr, formamide,	 0.03g BiOBr MO (50ml,2×10-5M)	500W Xenon lamp CO_2 reduction: 200mg BiOBr 300W Xe lamp	monolayered BiOBr>bulk BiOBr Degradation rate： MO 300min 33% CO_2 reduction performance: monolayered BiOBr>bulk BiOBr	[44]

BiOClBiOBr BiOI solvent-free grinding mechanical method; $Bi(NO_3)_3 \cdot 5H_2O$, KBr/I/Cl, agate mortar, ground for5min(0.5/1/2/3/5/10min) (a)BiOCl (d)BiOBr (g)BiOI	 10 mg photocatalyst RhB/MB(50 mL 5mg/L)	500W xenon lamp	BiOCl>BiOBr>BiOI	[45]

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