Hydrothermal Synthesis of Disk-Like Bi$_2$WO$_6$-BiPO$_4$ Heterojunctions and Enhanced Photocatalytic Performance for Rhodamine B Degradation

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Novel Bi$_2$WO$_6$-BiPO$_4$ photocatalysts with heterojunction structure were fabricated through a facile hydrothermal route. The photocatalytic properties of Bi$_2$WO$_6$-BiPO$_4$ composites were evaluated by photocatalytic degradation of rhodamine B (Rh B) under simulated sunlight irradiation. The results showed that Bi$_2$WO$_6$-BiPO$_4$ photocatalysts displayed much higher photocatalytic performances for Rh B degradation than the single BiPO$_4$ and Bi$_2$WO$_6$. The best photocatalytic activity of Bi$_2$WO$_6$-BiPO$_4$ with nearly 100% Rh B degradation located at molar ratio of 1:1 after 20 min irradiation. The enhanced photocatalytic performance could be mainly ascribed to the formation of heterojunction interface in Bi$_2$WO$_6$-BiPO$_4$ which facilitated the transfer and separation of photogenerated electron-hole pairs, as well as the strong visible light absorption originating from the sensitization role of Bi$_2$WO$_6$ to BiPO$_4$. It was also found that the photodegradation of Rh B molecules was mainly attributed to the oxidation action of the generated O$_2^-$ radicals and partly to the action of h$_{vb}^+$ via direct hole oxidation process.

**Key words:** Bi$_2$WO$_6$, BiPO$_4$, Heterojunction, Photocatalytic activity, Mechanism

I. INTRODUCTION

With the rising level of air and water pollution, researchers are giving more and more attention to environmentally friendly materials, especially photocatalysts [1, 2]. Since the photo-electrochemical water splitting was reported in 1972 [3], great progresses have been made on the research and application of photocatalysis both in energy and environmental fields. To date, researches focused mainly on two aspects: one is to improve the photocatalytic reactivity and efficiency by optimization of experiment conditions or by synthesizing new types of photocatalysts; the other is to design and develop visible-light-responsive photocatalysts, because the visible region constitute about 45% and UV region constituted 3%-5% of the total solar spectrum [4-6].

To develop new photocatalysts active under visible light, various efforts have been made in the past several years. Especially, related to the photocatalytic activity of Bi-ion containing compounds, such as BiVO$_4$ [7, 8], Bi$_2$WO$_6$ [9, 10], Bi$_2$MoO$_6$ [11], and BiPO$_4$ [12]. Currently, some new photocatalysts, mostly focused on the anions in the nonmetal oxy-acid salts, like PO$_4^{3-}$, SO$_4^{2-}$ have been reported to be effective to enhance the photocatalytic activity due to the strong bonding ability with H$_2$O$_2$, the high negative energy to draw the hole to the interface by the electrostatic force, and the chemical-redox inertness to the photogenerated electrons and holes [13, 14]. BiPO$_4$ is a new type inorganic nonmetal salt of oxy-acid photocatalyst. It exhibits a more superior photocatalytic activity than that of P$_2$O$_5$ on degradation of organic pollutants under UV irradiation [15-17]. However, no visible light response activity is still the largest obstacle for its further applications [18, 19]. Therefore, it is the most important mission to broaden the visible light absorption region and obtain high visible light induced photocatalytic performance of BiPO$_4$. Many processes have been made for BiPO$_4$ through constructing composite photocatalysts with other narrow band-gap semiconductors, including C$_3$N$_4$/BiPO$_4$ [20], AgBr/BiPO$_4$ [21], AgPO$_4$/BiPO$_4$ [22], BiOI/BiPO$_4$ [23], BiVO$_4$/BiPO$_4$ [24], and CdS/BiPO$_4$ [25]. Since the kinds of BiPO$_4$ composites are fairly limited, it is essential to look for suitable components that can effectively modify BiPO$_4$ and largely enhance its photocatalytic activity.

As one kind of the bismuth salt, bismuth tungstate (Bi$_2$WO$_6$, $E_g$=ca. 2.75 eV) has been intensively investigated due to its excellent visible-light photocatalytic activity [9, 10]. It was reported that Bi$_2$WO$_6$ could induce photocatalytic oxygen liberation from water and could decompose organic compounds and toxic gases, such as acetaldehyde, trichloromethane, biphenyl A and nitric oxide under visible light irradiation [26-28]. There-
fore, the combination of BiPO$_4$ and Bi$_2$WO$_6$ should be an ideal system to achieve good photocatalytic performance under visible light irradiation.

In this work, we reported a novel Bi$_2$WO$_6$/BiPO$_4$ composite with a heterojunction structure synthesized by a simple hydrothermal method for the first time. The photocatalytic activities of the Bi$_2$WO$_6$/BiPO$_4$ heterojunctions were evaluated by decomposing model of rhodamine B (Rh B) under simulated sunlight irradiation. The results indicate that Bi$_2$WO$_6$/BiPO$_4$ was a very efficient composite photocatalyst to degrade Rh B. The possible photocatalytic mechanism of the Bi$_2$WO$_6$/BiPO$_4$ composite photocatalysts was also discussed in detail.

II. EXPERIMENTS

A. Preparation of photocatalysts

All chemicals were analytic grade and used without further purification. Bi(NO$_3$)$_3$·5H$_2$O (2 mmol) was firstly dissolved with Na$_2$WO$_4$·2H$_2$O (1 mmol) or NaPO$_4$·12H$_2$O (1 mmol) in 10 mL water. For synthesis of Bi$_2$WO$_6$, the pH value of solution was adjusted to 3 by adding 1 mol/L HNO$_3$, the mixture was then transferred into a 20 mL Teflon-lined stainless steel autoclave, and heated at 160 °C for 24 h. For synthesis of BiPO$_4$, the pH value of solution was adjusted to 3 by adding 1 mol/L HNO$_3$, the mixture was then transferred into a 20 mL Teflon-lined stainless steel autoclave, and heated at 180 °C for 72 h. After reaction, the obtained solid was washed with distilled water three times, and dried at 80 °C for 24 h. For synthesis of Bi$_2$WO$_6$-BiPO$_4$ heterojunction, Bi(NO$_3$)$_3$·5H$_2$O (3 mmol) and total 2 mmol Na$_2$WO$_4$+NaPO$_4$ (mole ratios of W:P were 3:1, 1:1, 2:3, and 1:3, respectively) were dissolved in 40 mL water. The pH value of the mixture was adjusted to 3 by adding 1 mol/L HNO$_3$. The mixture was then transferred into a 20 mL Teflon-lined stainless steel autoclave, and heated at 180 °C for 72 h. After reaction, the obtained solid was washed with distilled water three times, and dried at 80 °C for 24 h. The obtained products were denoted as 3Bi$_2$WO$_6$-1BiPO$_4$, 1Bi$_2$WO$_6$-1BiPO$_4$, 2Bi$_2$WO$_6$-3BiPO$_4$, and 1Bi$_2$WO$_6$-3BiPO$_4$, respectively.

B. Characterization of photocatalysts

The crystal structures of the samples were characterized by X-ray diffraction (XRD) on a Rigaku (Japan) D/max 2500 X-ray diffractometer (Cu Kα radiation, λ=0.15418 nm). The morphologies and structure details of the as-prepared samples were detected by using field emission scanning microscopy (FESEM, JSM-6700F) and transmission electron microscopy (TEM, JEM-2100F). The optical properties were obtained by the photoluminescence (PL) measurement using HR800 LabRam Infinity Spectro photometer excited by a continuous He-Cd laser with a wavelength of 325 nm at a power of 50 mW. The UV-Vis diffuse reflectance spectra (DRS) were recorded using a scan UV-Vis spectrophotometer (UV-2550).

C. Photocatalytic activity

The photocatalytic activities of the as-prepared samples were evaluated using Rh B dye as a model compound. In experiments, the Rh B dye solution (5 μmol/L, 100 mL) containing 0.025 g of photocatalyst was mixed in a pyrex reaction glass. A 500 W Xe lamp was used to provide simulated sunlight irradiation. Prior to illumination, the suspension was strongly magnetically stirred for 30 min in the dark for adsorption/desorption equilibrium. Then the solution was exposed to light irradiation under magnetic stirring. At given time intervals, about 4 mL of the suspension was periodically withdrawn and analyzed after centrifugation. The Rh B concentration was analyzed by a UV-2550 spectrometer to record intensity of the maximum band at 552 nm in the UV-Vis absorption spectra.

D. Active species trapping experiments

To detect the active species during photocatalytic reactivity, some sacrificial agents, such as tert-butanol (t-BuOH), disodium ethylenediamine tetraacetic acid (EDTA-2Na) and 1,4-benzoquinone (BQ) were used as the hydroxyl radical (OH$^-$) scavenger, hole ($h^+$) scavenger and superoxide radical (O$_2$$^{−}$) scavenger, respectively. The method was similar to the former photocatalytic activity test with the addition of 1 mmol of quencher in the presence of Rh B.

III. RESULTS AND DISCUSSION

Figure 1 displays the XRD patterns of the as-prepared BiPO$_4$, Bi$_2$WO$_6$, and Bi$_2$WO$_6$-BiPO$_4$ composites. The diffraction peaks of BiPO$_4$ sample can be assigned to the monoclinic structure of BiPO$_4$ (JCPDS 15-0767). As can be seen in the pattern of Bi$_2$WO$_6$ sample, the diffraction peaks can be perfectly indexed to orthorhombic Bi$_2$WO$_6$ crystal phase (JCPDS 39-0256). No peaks of any other impurities were detected, showing that pure BiPO$_4$ and Bi$_2$WO$_6$ were formed. The Bi$_2$WO$_6$-BiPO$_4$ composites exhibited a coexistence of both BiPO$_4$ phase and Bi$_2$WO$_6$ phase, showing that the mixture of BiPO$_4$ and Bi$_2$WO$_6$ is the main existing form of Bi$_2$WO$_6$-BiPO$_4$ composites and no single W element was doped. Furthermore, with increasing BiPO$_4$ content, the intensities of diffraction peaks of monoclinic BiPO$_4$ increased.
Disk-Like Bi$_2$WO$_6$-BiPO$_4$ Heterojunctions

FIG. 1 XRD patterns of the as-prepared BiPO$_4$, Bi$_2$WO$_6$, and Bi$_2$WO$_6$-BiPO$_4$ composites.

The surface morphologies and sizes of the obtained Bi$_2$WO$_6$, BiPO$_4$, and Bi$_2$WO$_6$-BiPO$_4$ composites with different BiPO$_4$ contents were characterized by SEM, as shown in Fig.2. For the pure Bi$_2$WO$_6$ (Fig.2(a)), it consists of regular disk-like crystals with diameters of 1–1.5 μm, widths of about 100 nm. Differently, the pure BiPO$_4$ product is irregularly shaped flaky crystals with sizes between 200 and 800 nm (Fig.2(b)). As for the Bi$_2$WO$_6$-BiPO$_4$ composites (Fig.2 (c)–(f)), it can be observed that the morphology is disk-like. Figure 2(g) shows the magnified SEM images of 1Bi$_2$WO$_6$-1BiPO$_4$ composite. It can be seen that the disk-like nanostructure is composed of nanosheets. In such a way, Bi$_2$WO$_6$ and BiPO$_4$ would contact extensively meanwhile the heterojunction interfaces between Bi$_2$WO$_6$ and BiPO$_4$ might be efficiently generated.

In order to further ascertain the heterojunction structure between Bi$_2$WO$_6$ and BiPO$_4$, 1Bi$_2$WO$_6$-1BiPO$_4$ sample was investigated by TEM and HRTEM. Figure 3(a) discloses the disk-like morphology of the composite. The HRTEM image in Fig.3(b) clearly exhibits the fringes with the lattice spacing of 0.315 and 0.131 nm, which can be indexed to the (131) plane of Bi$_2$WO$_6$ and (421) plane of BiPO$_4$, respectively, well confirming the existence of Bi$_2$WO$_6$-BiPO$_4$ heterojunction. It is expected that Bi$_2$WO$_6$-BiPO$_4$ heterojunction could effectively hinder the recombination of photoinduced electron-hole pairs and enable Bi$_2$WO$_6$/BiPO$_4$ composites to acquire highly photocatalytic activities.

The UV-Vis diffuse reflectance spectra (DRS) of the as-prepared samples are presented in Fig.4(a). Obviously, BiPO$_4$ can merely respond to the ultraviolet light with the absorption band edge at about 350 nm. After the deposition of Bi$_2$WO$_6$, the light absorption of 1Bi$_2$WO$_6$-1BiPO$_4$ was significantly broadened to the visible light range, which indicates that Bi$_2$WO$_6$ is a good visible light sensitizer to BiPO$_4$. The band gap energies of Bi$_2$WO$_6$ and BiPO$_4$ can be calculated by the following formula [29]:

$$a\nu = A(\nu - E_g)^n/2$$

where $a$, $\nu$, $E_g$, and $A$ are absorption coefficient, the light frequency, the band-gap energy, and a constant, respectively. Among these parameters, $n$ is determined by the type of optical transition of a semiconductor ($n$=1,

FIG. 2 FESEM images of the as-prepared samples. (a) Bi$_2$WO$_6$, (b) BiPO$_4$, (c) 3Bi$_2$WO$_6$-1BiPO$_4$, (d) and (g) 1Bi$_2$WO$_6$-1BiPO$_4$, (e) 2Bi$_2$WO$_6$-3BiPO$_4$, (f) 1Bi$_2$WO$_6$-3BiPO$_4$. 

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FIG. 3 TEM (a) and HRTEM (b) image of the as-prepared 1Bi$_2$WO$_6$-1BiPO$_4$ sample.

FIG. 4 (a) UV-Vis DRS of the as-prepared BiPO$_4$, Bi$_2$WO$_6$, and 1Bi$_2$WO$_6$-1BiPO$_4$ composite. (b) The plots of $(\alpha h\nu)^{1/2}$ versus photon energy $(h\nu)$ for the band-gap energies of Bi$_2$WO$_6$ $(n=1)$ and BiPO$_4$ $(n=4)$.

for a direct transition and $n=4$ for an indirect transition). For BiPO$_4$ and Bi$_2$WO$_6$, the values of $n$ are 4 and 1 for the indirect transition and direct transition [12, 30], respectively. According to Eq.(1), the band-gap energy $(E_g)$ of Bi$_2$WO$_6$ can be estimated from a plot of $(\alpha h\nu)^2$ versus energy $(h\nu)$, and the $E_g$ of BiPO$_4$ can be estimated from a plot of $(\alpha h\nu)^{1/2}$ versus energy $(h\nu)$. Thus, the band gaps of the as-prepared BiPO$_4$ and Bi$_2$WO$_6$ are estimated to be 3.44 and 2.44 eV, respectively. The 1Bi$_2$WO$_6$-1BiPO$_4$ composite exhibited a mixed absorption property of BiPO$_4$ and Bi$_2$WO$_6$. The significantly enhanced absorption intensity in the visible-light region results from the presence of Bi$_2$WO$_6$, which functions as a light sensitizer in the heterojunctions.

Photodegradation experiment of Rh B was carried out under simulated sunlight irradiation in order to test the photocatalytic performance of Bi$_2$WO$_6$-BiPO$_4$ photocatalysts. The photodegradation for Bi$_2$WO$_6$-BiPO$_4$ samples is displayed in Fig.5. For comparison, the photodegradation of Rh B by pure Bi$_2$WO$_6$ and BiPO$_4$ and that without any catalyst were also carried out. The blank test demonstrates that the degradation of Rh B was extremely slow without any photocatalyst under simulated sunlight illumination. Only 11% of Rh B molecules could be decolorized over BiPO$_4$ after 20 min irradiation, while 50.5% could achieve photocatalytic decolorization over Bi$_2$WO$_6$ under the same condition. This is generally consistent with previous reports [24, 31]. As expected, all of the Bi$_2$WO$_6$-BiPO$_4$ photocatalysts exhibited higher photocatalytic activities than the pure BiPO$_4$ and Bi$_2$WO$_6$ sample. The highest activity was obtained over the 1Bi$_2$WO$_6$-1BiPO$_4$ sample, where about 100% Rh B was decomposed after 20 min irradiation. With increasing Bi$_2$WO$_6$ contents (Bi$_2$WO$_6$:BiPO$_4$ mole ratio from 1:3 to 3:1), the photocatalytic activity of Bi$_2$WO$_6$-BiPO$_4$ first increased and then decreased. These changes in the photocatalytic activity could be due to the synergetic effects of light absorption and heterojunction structure of Bi$_2$WO$_6$-BiPO$_4$. As the Bi$_2$WO$_6$ content increased, the visible light absorption of Bi$_2$WO$_6$-BiPO$_4$ strengthened and generated more electron-hole pairs, and more Bi$_2$WO$_6$-BiPO$_4$ heterojunction was formed, contributing to the separation of electron-hole pairs. However, when the Bi$_2$WO$_6$ content was above the optimal value (Bi$_2$WO$_6$:BiPO$_4$ mole ratio of 1:1), the efficient heterojunction interface did not increase significantly whereas the excessive narrow band-gap Bi$_2$WO$_6$ could act as the recombination center of electrons and holes. Consequently, the separation efficiency of electron-hole pairs decreased and further restrained the photocatalytic activity. Our results of foregoing investigations
FIG. 6 Stability evaluation for 1Bi$_2$WO$_6$-1BiPO$_4$: five reaction cycles for photodegradation of Rh B under simulated sunlight irradiation.

FIG. 7 XRD patterns and SEM images of the as-prepared 1Bi$_2$WO$_6$-1BiPO$_4$ catalyst before and after photocatalysis of Rh B for five catalytic runs.

The stability of the 1Bi$_2$WO$_6$-1BiPO$_4$ heterojunction was studied by recycling the photocatalyst used to degrade Rh B. As shown in Fig.6, after five cycles, the photocatalyst still decomposed Rh B with only a slight loss of activity. In addition, the present photocatalyst can be easily separated from the aqueous system by a simple filtration due to its large size.

Figure 7 shows the XRD patterns and SEM images of the 1Bi$_2$WO$_6$-1BiPO$_4$ catalyst before the photocatalytic reaction and after the catalytic reaction. After five catalytic runs, the position and the ratio of peaks were nearly the same as that of fresh photocatalyst.

PL spectra originate from the migration, transfer, and separation efficiency of the photogenerated charge carriers in a semiconducting material. There is a strong correlation between PL intensity and the photocatalytic performance. Higher PL intensity indicates the higher recombination of the charge carriers, which results in lower photocatalytic activity. The comparison of PL spectra of BiPO$_4$, Bi$_2$WO$_6$, and 1Bi$_2$WO$_6$-1BiPO$_4$ at excitation wavelength of 325 nm is shown in Fig.8. The main emission peak centers at about 550 nm for the pure BiPO$_4$ sample, which can be ascribed to the band gap recombination of electron-hole pairs. Compared with BiPO$_4$, addition of Bi$_2$WO$_6$ does not alter the spectral position of the peaks, but reduces the relative intensity of PL spectra. These results indicate that the heterojunction effect of BiPO$_4$ and Bi$_2$WO$_6$ contributes to the effective electron-hole pair separation, which could be a reason for the BiPO$_4$-Bi$_2$WO$_6$ heterostructures showing superior photocatalytic activity.

The above results reveal that the formation of heterojunction combining BiPO$_4$ with Bi$_2$WO$_6$ can enhance...
their photocatalytic performances under simulated sunlight irradiation. In order to clearly understand the formation of Bi$_2$WO$_6$-BiPO$_4$ heterojunction, the initial energy band structures of Bi$_2$WO$_6$ and BiPO$_4$ were provided. The band positions of Bi$_2$WO$_6$ and BiPO$_4$ were calculated by the following empirical formulas [32]:

$$E_{VB} = X - E^c + 0.5E_g$$

$$E_{CB} = E_{VB} - E_g$$

where $E_{VB}$ is the valence band edge potential, $E_{CB}$ is the conduction band edge potential, $X$ is the electronegativity of the semiconductor, which is the geometric mean of the electronegativity of the constituent atoms, and the values of $X$ for Bi$_2$WO$_6$ and BiPO$_4$ are ca. 6.22 and 6.49 eV, respectively. $E^c$ is the energy of free electrons on the hydrogen scale (about 4.5 eV). $E_g$ is the band gap energy of the semiconductor. Based on the band gap positions, the CB and VB edge potentials of Bi$_2$WO$_6$ are determined to be 0.60 and 3.04 eV, respectively. The CB and VB edge potentials of BiPO$_4$ are determined to be 0.27 and 3.71 eV, respectively. The energy band structure diagram of Bi$_2$WO$_6$ and BiPO$_4$ is thus schematically illustrated, as shown in Fig. 9. Once the heterojunction is irradiated by simulated sunlight irradiation, both Bi$_2$WO$_6$ and BiPO$_4$ can be excited and produce photogenerated electron-hole pairs. Since the conduction band potential of BiPO$_4$ is more negative than those of Bi$_2$WO$_6$, photogenerated electrons on the CB of BiPO$_4$ can easily transfer to the CB of Bi$_2$WO$_6$. This transference effectively suppresses the charge recombination, and thus results in an enhanced photocatalytic activity.

Another series of tests were conducted to probe the mechanism responsible for this photocatalysis. In order to ascertain the active species in the degradation process, some sacrificial agents, such as tert-butanol ($t$-BuOH), disodium ethylenediamine tetraacetic acid (EDTA-2Na) and 1,4-benzoquinone (BQ) were used as the hydroxyl radical (OH$^-$) scavenger, hole (h$^+$) scavenger and superoxide radical (O$_2^-$) scavenger, respectively. As shown in Fig. 10, with 1 mmol of EDTA-2Na as a hole scavenger added to the solution, the rate for degradation of Rh B over 1Bi$_2$WO$_6$-1BiPO$_4$ sample was slightly depressed, indicating that a few of holes were involved in the degradation of Rh B. When 1 mmol of $t$-BuOH as a scavenger for OH$^-$ radical species was added, no obvious decrease of degradation rate was observed, indicating the absence of OH$^-$ radical species. However, with the addition of 1 mmol of O$_2^-$ scavenger BQ, the degradation of Rh B was significantly depressed, suggesting that the O$_2^-$ pathways played a crucial role in the process of Rh B oxidation. These observations verify that the O$_2^-$ radicals (produced from the dissolved oxygen by the reduction of photogenerated electrons) and a few holes mainly contribute to the decomposition of Rh B molecules over 1Bi$_2$WO$_6$-1BiPO$_4$ under simulated sunlight irradiation. Hydroxyl radical was verified to be insignificant for the decomposition of Rh B.

The above results reveal that the active species including h$^+$, O$_2^-$ are responsible for the degradation of Rh B over Bi$_2$WO$_6$-BiPO$_4$ photocatalyst under simulated sunlight illumination. On the basis of the band gap structure of Bi$_2$WO$_6$-BiPO$_4$ and the effects of scavengers, a possible pathway for the photocatalytic degradation of Rh B with Bi$_2$WO$_6$-BiPO$_4$ composite is proposed as follows:

$$\text{Bi}_2\text{WO}_6-\text{BiPO}_4 + h\nu \rightarrow \text{Bi}_2\text{WO}_6(h^+_\text{vb}) + \text{Bi}_2\text{WO}_6(e^-) + \text{BiPO}_4(h^+_{\text{cb}}) + \text{BiPO}_4(e^-)$$

$$\text{Bi}_2\text{WO}_6(e^-) + \text{O}_2 \rightarrow \text{O}_2^-$$

$$h^+_{\text{cb}} + \text{O}_2^- + \text{Rh B} \rightarrow \text{products}$$

FIG. 9 Schematic diagrams for (a) energy bands of Bi$_2$WO$_6$ and BiPO$_4$ before contact and (b) the formation of a junction and transfer of photoinduced electrons from BiPO$_4$ to Bi$_2$WO$_6$ under simulated sunlight irradiation.

FIG. 10 Trapping experiment of active species during the photocatalytic degradation of Rh B over 1Bi$_2$WO$_6$-1BiPO$_4$ sample under simulated sunlight irradiation.
ated electron-hole pairs were separated effectively through the direct hole oxidation process. In addition, holes in the Bi$_2$WO$_6$ might directly oxidize the Rh B through the direct hole oxidation process.

Based on the above analysis, the photogenerated electron-hole pairs were separated effectively through the heterojunction interface formed in the Bi$_2$WO$_6$/BiPO$_4$ composite photocatalysts. On the other hand, the strong visible light absorption was also favorable for the photocatalytic activity enhancement of Bi$_2$WO$_6$/BiPO$_4$. In a word, the enhanced photocatalytic activity of Bi$_3$WO$_6$-BiPO$_4$ heterostructure could be mostly attributed to the heterojunction structure as well as the strong visible light absorption resulting from the sensitization of Bi$_2$WO$_6$ to BiPO$_4$.

**IV. CONCLUSION**

The novel Bi$_2$WO$_6$/BiPO$_4$ photocatalyst with heterojunction was successfully prepared by a facile hydrothermal method. The Bi$_2$WO$_6$/BiPO$_4$ heterostructures exhibited much higher photocatalytic activity for the degradation of rhodamine B compared to single Bi$_2$WO$_6$ and BiPO$_4$. The results indicated that the strong sensitization of Bi$_2$WO$_6$ to BiPO$_4$ broadened the photoabsorption of BiPO$_4$, which ensured that enough photogenerated electron-hole pairs could be generated. Moreover, the heterojunction structure of Bi$_2$WO$_6$/BiPO$_4$ facilitated the efficient separation of photogenerated electron-hole pairs, greatly promoting the photocatalytic efficiency of BiPO$_4$. Thus, it will be a potential way to reform wide band-gap semiconductor BiPO$_4$ with narrow band-gap semiconductors to remove the harmful organic pollutants rapidly in the future.

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