# Application of $BiVO_4$ Nanocomposite for Photodegradation of Methyl Orange

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**Abstract**

In this work, $BiVO_4$–graphene photocatalyst was prepared by a facile one-step hydrothermal method and characterized by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM). The photocatalytic activity of this compound was investigated by destruction of methyl orange (MO) under visible light irradiation. The photodegradation results show that the prepared BVG compound has higher photocatalytic activity rather than pure $BiVO_4$ compound. This compound can degrade 98% of MO under visible light irradiation. This work indicates that $BiVO_4$ compounds are excellent compounds for pollutant degradation under visible light irradiation.

**Keywords:** Nanocomposite, $BiVO_4$, Photodegradation, Methyl Orange.

# 1 Introduction

The development of semiconductor photocatalysts for degradation of organic pollutants under visible-light irradiation is a challenging and obligatory topic. In recent years, semiconductor photocatalysts have attracted great attention due to their potential application in water splitting and organic pollutant photodegradation [1]. To date,$TiO_2$ as a useful material for many photocatalytic reactions has been intensively investigated. However, its application is limited by its wide band gap (3.2 eV) which requires ultraviolet irradiation for photocatalytic activation [2, 3]. Therefore, developing alternative materials that are capable of using solar energy has become one of the most challenging topics today. Great efforts have been exerted to develop visible-light responsive photocatalysts in the degradation of dyes. Various semiconductor photocatalysts, such as $WO_3, ZnO, BiVO_4$ and CdS have been investigated for photocatalytic degradation of water pollutants under visible light irradiation [4].
Among these works, $BiVO_4$ is one of attractive semiconductors with three crystalline phases, tetragonal zircon-type (z-t), tetragonal sheelite-type (s-t), monoclinic sheelite-type (s-m). Monoclinic $BiVO_4$ is generally considered to be more active than other phases [5].$BiVO_4$ is nontoxic and chemically stable in aqueous solution and narrow band gap (2.4 eV) of $BiVO_4$ can provide effective utilization of the visible light region [6].
Graphene materials have shown great potential as the catalysts in the photocatalysis process in recent years. Its unique properties such as 2D structure, high mobility of charge carriers, theoretically large surface area ( 2600 m2/g), etc., made graphene as a prospective candidate for designing of photocatalytically active composites [7, 8].
In this work, we synthesized monoclinic structure of $BiVO_4$ and $BiVO_4$–graghene compound. Photocatalytic activities of the prepared samples were evaluated by the methyl orange decomposition under visible irradiation.

# 2 Experimental

## 2.1 Synthesis of Bismuth Vanadate

$Bi(NO_3)_3{\cdot}5H_2O$ (1 mmol, 0.485 g) was dissolved in 20 ml of 1 M $HNO_3$ by stirring for 30 min at room temperature. Alkaline solution of $NH_4VO_3$ was prepared by dissolving 0.117 g (1 mmol) of $NH_4VO_3$ in 20 ml of 0.5 M NaOH under stirring for 30 min at room temperature. The $NH_4VO_4$ solution was added drop wise to the $Bi(NO_3)_3$ solution with stirring to get a clear solution. The resultant was transferred to a 100 ml Teflon-lined stainless steel autoclave, sealed and heated at 120 °C for 24 h under autogenous pressure. The obtained samples were filtered, washed with deionized distilled water, followed by absolute ethanol. Finally, the obtained solid samples were dried in a hot air oven [9].

### 2.2 Preparation of the $BiVO_4$-graphene Nanocomposite

The prepared solution was named A. A facile one-step solvothermal method was used to synthesize the $BiVO_4$–graghene nanocomposite by dissolving 0.5w% of graphene. Then, 0.485 g of the prepared $BiVO_4$ powder was added into solution A. Then, the suspensions were transferred into a 100 ml Tefon-sealed autoclave and kept at 120° C for 24 h. The resulting products were recovered by centrifugation, rinsed with DI water and ethanol, as well as dried at 60° C for 6 h in hot air oven.

## 3 Results and Discussion

### 3.1 X-ray Powder Diffraction

The XRD pattern of the prepared $BiVO_4$–graghene nanocomposite are shown in Fig. 1. The characteristic peak of graphene is at $2\theta = 25°$ . In the XRD pattern of the $BiVO_4$–graghene photocatalyst, the broad peak of graphene is observed at $2\theta = 25°$ . Due to the high crystalinity of $BiVO_4$ and subsequently its sharp peaks, the intensity of graphene peak is low. Due to the high purity of the synthesized samples, no impurity peaks are observed in the X-ray diffraction pattern of this compound.

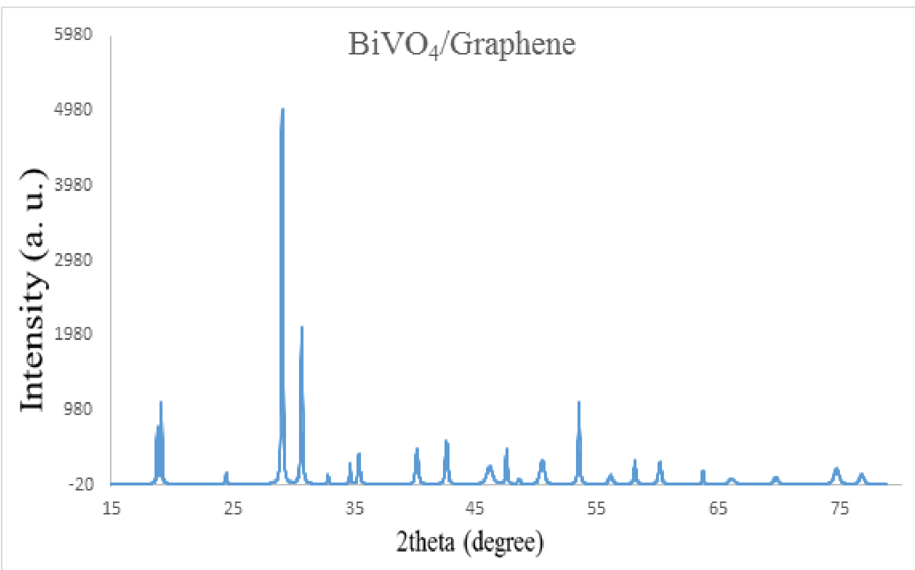


Figure 1: The XRD pattern of the prepared $BiVO_4$–graghene nanocomposite

## 3.2 DRS Analysis of the Prepared Sample

The DRS analysis of the prepared sample is shown in Fig 2. Based DRS analysis the band gap of $BiVO_4$ has been calculated 2.47 eV. Graphene with high charge mobility can decrease the recombination parameter and decrease the band gap that consequently increase the photocatalytic activity.

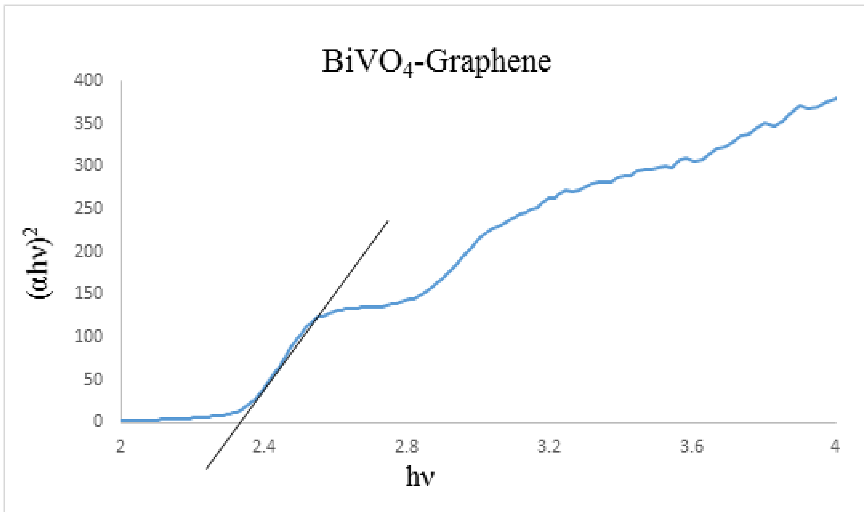


Figure 2: DRS analysis of the prepared $BiVO_4$–graghene nanocomposite

## 3.3 Morphological Characterization

The SEM image of the $BiVO_4$–graghene sample is shown in Fig. 3. The sheet like morphology of the $BiVO_4$–graghene sample is obvious in the SEM image of this compound. Due to the sheet like morphology of the graphene plates, the $BiVO_4$ plates decorated on the graphene sheets arrange in the sheet like morphology.

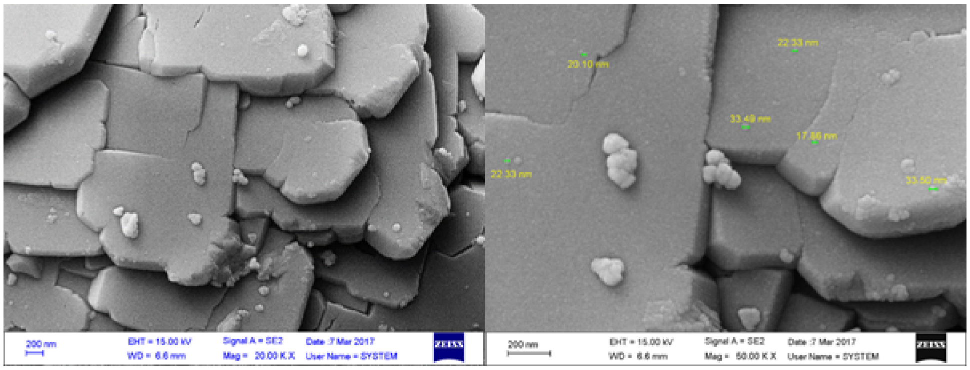


Figure 3: SEM image of the prepared $BiVO_4$–graghene compound

## 3.4 IR Spectra of the Prepared Sample

The IR spectrum of $BiVO_4$-graphene shows in Fig. 4 . In this IR spectrum, the strong and broad peak at 1261 $cm^{-1}$ responds to the $BiVO_4$ vibrational system.

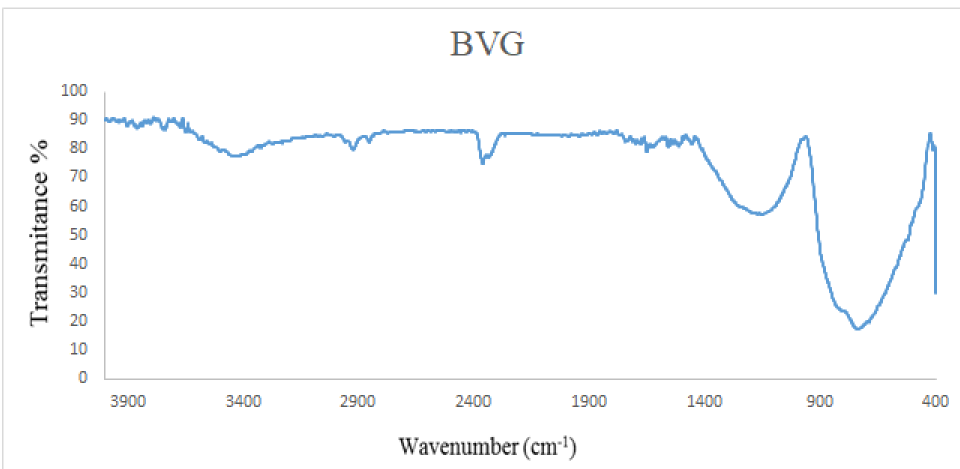


Figure 4: IR spectra of the prepared sample $BiVO_4$-graphene

## 3.5 Photocatalytic Activity of the Prepared Samples

The photocatalytic activity of $BiVO_4$ and $BiVO_4$–graghene samples was evaluated by the degradation of methyl orange in the aqueous solution (10 ppm) under the visible light irradiation. As shown in Fig. 5, under the visible light irradiation 69% of the methyl orange dye was destructed in the presence of the

$BiVO_4$ sample after 240 min and 98% of the methyl orange dye was destructed in the presence of the $BiVO_4$–graghene sample after 180 min. The results showed that $BiVO_4$–graghene nanocomposite has higher photocatalytic activity than pure $BiVO_4$. In the $BiVO_4$–graghene nanocomposite, electron-hole pairs are generated after excitation of $BiVO_4$ with visible light irradiation. Due to the low band gap of $BiVO_4$, this low power of visible light is sufficient to excite $BiVO_4$ photocatalyst. One of the important parameters of photocatalysis reactions is the recombination process. This parameter, especially is happening in the low band gap semiconductors. The recombination process decreases the efficiency of the photocatalytic reactions. In $BiVO_4$–graghene nanocomposite, due to the presence of graphene, the prepared electron-hole pairs move to graphene and reach to the photocatalyst surface. Therefore, The recombination process is reduced in the photocatalytic reaction of this nanocomposite. The high charge conductivity of graphene increases the migration of charges into the photocatalyst surface. The synergistic effect between graphene and $BiVO_4$, The proper adjustment between the valence and conduction band of graphene and $BiVO_4$, and proper composition between these two components yields the high photocatalytic activity of the prepared $BiVO_4$–graghene nanocomposite.

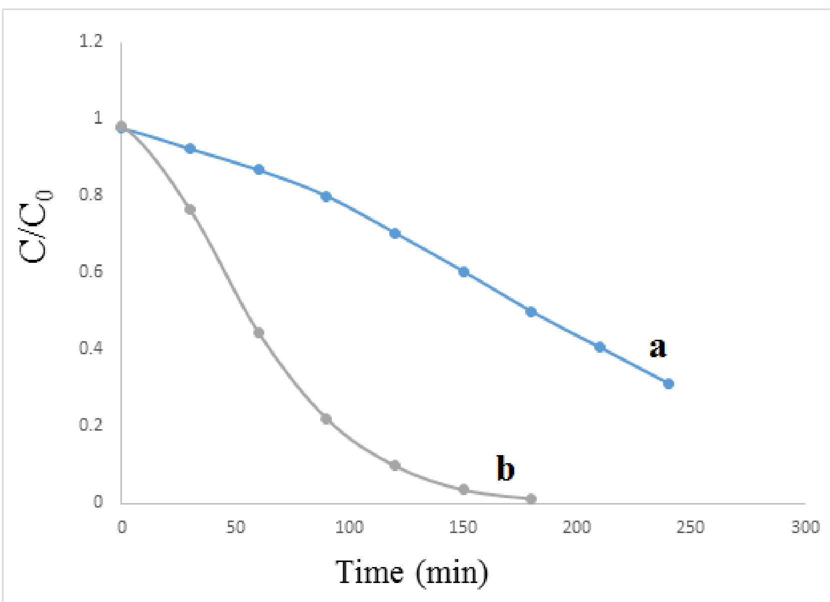


Figure 5: The photodegradation results of MO over a)$BiVO_4$, b)$BiVO_4$-graphene nanocomposite under visible light irradiation.

# 4 Conclusion

In this work we prepared $BiVO_4$ and $BiVO_4$–graphene with the simple hydrothermal method. The photocatalytic activity of the prepared $BiVO_4$ is low due to the low band gap of this compound. The recombination process is high in $BiVO_4$. The photodegradation results show that the composition of graphene and $BiVO_4$ increases effectively the photocatalytic activity of the prepared photocatalyst. Thus, the recombination process of $BiVO_4$ decreases after composition with graphene.


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