One-step synthesis of rod-on-plate like 1D/2D-NiMoO₄/BiOI nanocomposite for an efficient visible light driven photocatalyst for pollutant degradation

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Abstract

A visible light driven 1D/2D-NiMoO₄/BiOI nanocomposite photocatalyst was constructed by single step solvothermal method. Here, various composition of NiMoO₄/BiOI nanocomposites were prepared by loading different amounts of NiMoO₄ (1, 2, 3 wt %) to the BiOI. Among the as-prepared photocatalysts, 1 wt % of NiMoO₄ on BiOI (NMBI-1) showed superior photocatalytic activity (92.7 %) under visible light irradiation. On analysis, the optimized NMBI-1 exhibited a lower bandgap energy value of 1.64 eV and also found to show around 2 and 3.7-times higher degradation ability for the removal of MB than the pure NiMoO₄ and BiOI respectively. In addition, the optimized NMBI-1 nanocomposite photocatalyst exhibited excellent photostability and recyclability properties. The charge carriers on the interface of the NiMoO₄ and BiOI enabled the easy transfer via the newly formed heterojunction, thereby increasing the photocatalytic performance. Additionally, the radical scavengers such as h⁺ and ·OH were found to be the major species in the removal of MB under visible light illumination. Therefore, the 1D/2D-NiMoO₄/BiOI nanocomposite photocatalyst materials could possibly be considered for the wastewater remediation processes.

1. Introduction

Environmental pollution is considered as a major crisis, that creates global damage, owing to the development of industries and urbanization. Reusing of water from the industrial effluent has to be considered as a most needful measure to compensate the increasing water scarcity (Abdelkader et al. 2019). Continuous release of harmful effluents from various industries like textile, printing, paper, cosmetics, pharmaceuticals, etc., uses large amount of dyes to increase the quality of the products and their discharged effluents containing vast amount of toxic and hazardous organic pollutants are directly discharged into the aquatic environment. These dyes even at low concentration can pose harmful health effects on aquatic life and human beings. Hence, it is a dire need to eliminate these harmful contaminants from the wastewater prior reaching to the environment (Malathi et al. 2018; Koe et al. 2020; Mansouri et al. 2019). Various wastewater remediation methods such as adsorption, precipitation, sonolysis, reverse osmosis, photo-Fenton process, etc., are operative but their high cost and creation of secondary pollutants limits their practical application in large scale (Tran et al. 2020; Hu and Zhang et al. 2018; Louhich et al. 2019). It would be a much more challenging task for practical application to imply a green method to eliminate toxic pollutants. In regard to this, advanced oxidation process (AOPs) method with a semiconductor photocatalyst is considered as an eco-friendly process to degrade the pollutant without producing any secondary pollutants and also being a cost-effective method (Khatri et al. 2018). For the environmental remediation, TiO₂ is a commonly used photocatalyst with advantageous properties like non-toxicity, high stability, cheap, but its wide band gap energy (3.2 eV) makes it as unfavorable for the visible light absorption (Li et al. 2020). To resolve this, it is essential to develop a visible light active photocatalyst with low bandgap energy. In this regard, a wide range of photocatalysts were prepared and employed such as WO₃ (Senthil et al. 2019), gC₃N₄ (Priya et al. 2020), ZnO (Zhang et al. 2019), Bi₂WO₆ (Ju et al. 2014), BiYO₃ (Hou et al. 2019), Bi₂S₃ (Xu et al. 2019), AgVO₃ (Bavani et al. 2021), MoS₂ (Senthil

et al. 2019), FeOOH (Malathi et al. 2018) and etc., for wastewater remediation. Presently, bismuth-based semiconductor photocatalysts are widely preferred choice among visible light active photocatalysts. Among them, BiOX (X= F, Cl, Br, I) photocatalysts have received extensive attention from researchers due to their inexpensiveness over other photocatalysts and unique layered structure that governs the migration of charge carriers (e^-/h^+) (Malathi and Chang et al. 2018; Xu et al. 2020; Alzamly et al 2019). Specifically, BiOI is one such effective photocatalyst with more stability and has lower bandgap energy (1.8-2.0 eV) which facilitates the high absorption in visible region. However, its higher photodegradation efficiency is restricted by the rapid rejoining of photoproduced e^-h^+ pairs as reported earlier (Hu et al. 2020). To address this problem, various strategic methods have been employed, (i) morphology tailored BiOI, (ii) coupling with a solid mediator (metal or non-metal), (iii) coupling with different semiconductor materials. Ideally, the formation of heterojunction with various semiconductors has been considered as an effective strategic method to promote the separation of charge carriers (e^-h^+), which increases the photodegradation ability of BiOI. On this basis, $NiMoO_4$ is selected to couple with BiOI to form $NiMoO_4/BiOI$ nanocomposite in this study, owing to its low bandgap energy (~ 2.2 eV) and easy availability. To the best of our knowledge, no study has been reported earlier for the degradation of organic dye in the visible light irradiation of $NiMoO_4/BiOI$ photocatalyst.

In the present work, we have constructed $NiMoO_4$ on BiOI composite by using single step solvothermal method, by differing the wt. % of $NiMoO_4$. The photocatalytic behavior of the photocatalysts are analyzed against the degradation of methylene blue (MB). The results presented the superior photocatalytic, photo recyclability and stability characteristics of 1D/2D- $NiMoO_4/BiOI$ composite. Hence, we believe that our developed composite photocatalyst could be a promising material to employ them in the remediation of wastewater.

2. Materials And Methods

2. 1 Materials

Nickel nitrate hexahydrate ($Ni(NO_3)_2 \cdot 6H_2O$), sodium molybdate dihydrate ($Na_2MoO_4 \cdot 2H_2O$), ethylene glycol and isopropyl alcohol were acquired from Sigma-Aldrich. Bismuth nitrate pentahydrate ($Bi(NO_3)_3 \cdot 5H_2O$) potassium iodide (KI), and Triton X-100 were procured from Qualigens, India. Ammonium oxalate, benzoquinone, methylene blue, and ammonia solution (NH_3) were purchased from SDFCL, India. All these chemicals were used without further purification.

2. 2. Preparation of $NiMoO_4$ nanorods

$NiMoO_4$ nanorods were prepared by hydrothermal method. In this method, 2.5 mmol of $Ni(NO_3)_2 \cdot 6H_2O$ and $NaMoO_4$ were dissolved in 60 mL of DI water with constant stirring for 30 min. After stirring, the above mixture is transferred into the Teflon autoclave heated at 180 °C for 24 h. Then the precipitate is filtered, dried at 60 °C for 3 h and then annealed at 400 °C for 4 h.

2.3. Preparation of 1D/2D-NiMoO₄/BiOI nanocomposite

The NiMoO₄/BiOI nanocomposite photocatalyst were fabricated using simple single step solvothermal method. Herein, 5 mmol of Bi(NO₃)₃ · 5H₂O dissolved in 30 mL of ethylene glycol was added to 5 mmol of KI in 30 mL of water with constant stirring for 30 min. After that, varying amounts of the NiMoO₄ (1, 2, 3, 4 wt%) were added to the above mixture followed by 30 min of stirring. Finally, the mixture was transferred into a Teflon lined autoclave and the reaction was executed at 160 °C for 20 h. At last, the obtained precipitates are washed with ethanol and water for several times and dried at 80 °C for 4 h. In addition, the as-prepared NiMoO₄/BiOI nanocomposite with varying 1, 2, 3 wt% of NiMoO₄ were indicated as NMBI-1, NMBI-2 and NMBI-3 respectively. Furthermore, the pure BiOI was prepared without NiMoO₄. The Fig. 1 shows the schematic representation for the synthesis of 1D/2D-NiMoO₄/BiOI nanocomposites.

2.4. Material characterization

The crystal phase formation of the photocatalyst was investigated by powdered X-ray diffractometer Mini Flex II instrument with Cu K α radiation (λ = 0.1542 nm) and Fourier transform infrared spectra was performed by JASCO-4600 spectrometer. The photoluminescence (PL) and UV-vis diffuse reflection spectra (UV-vis DRS) were studied with Jobin Yvon Fluorolog-3-11 spectrofluorometer and JASCO-V670 correspondingly. The surface morphology of the samples was investigated by transmission electron microscopy (HR-TEM) JEOL-6330 TEM.

2.5. Photocatalytic degradation experiment

The photocatalytic degradation ability of the as-prepared photocatalysts were examined over the degradation of methylene blue (MB) dye under visible light irradiation using 250 W tungsten lamp as a light source. In this experiment, 75 mg of photocatalyst was added to 75 mL of MB (2X10⁻⁴ M) dye solution. Prior to irradiation of visible light, the solution was kept under dark for 45 min for sorption equilibrium. Under irradiation of visible light, 5 mL of aliquots were drawn at regular time intervals, after separating out the photocatalyst by centrifugation, the concentration of MB was evaluated by the maximum wavelength at λ_{max} = 664 nm using UV-Vis spectrophotometer.

2.6. Photoelectrochemical studies

The photoelectrochemical properties of the as prepared photocatalysts were examined using electrochemical work station containing three electrodes, Pt electrode as counter electrode, Ag/AgCl electrode as reference electrode and the photocatalyst coated FTO plate as working electrode. 0.1 M Na₂SO₄ was used as an electrolyte. The working electrode was prepared by doctor blade method, where 10 μ L of Triton X-100 and 20 μ L of water was added with 5 mg of photocatalyst. The mixture was ground well, and the slurry of the mixture was coated over the conducting surface of FTO plate (0.5X0.5 cm²) followed by drying at 80 °C for 6 h.

3. Results And Discussion

The crystal structure and phase purity of the fabricated photocatalysts were confirmed by X-ray diffraction studies. The XRD patterns of the pure BiOI, pure NiMoO₄ and NiMoO₄/BiOI nanocomposites are presented in Fig. 1a. In Fig. 1a, the diffraction patterns of NiMoO₄ exhibits monoclinic phase structure and are well indexed in correlation with JCPDS No. 45–0142 (He et al. 2014). The tetragonal phase structure of the BiOI seem to be well matched with JCPDS No. 10–0445 (Bavani et al. 2021). The NiMoO₄/BiOI nanocomposites shows decrease in the peak intensity of BiOI on adding NiMoO₄. But there are no characteristic peaks of NiMoO₄ are noticed, due to the low concentration of NiMoO₄ in the NiMoO₄/BiOI nanocomposite. Figure 1b displays the FT-IR spectrum of bare BiOI, bare NiMoO₄ and different NiMoO₄/BiOI nanocomposite photocatalysts. From the Fig. 1b, the peaks observed at 478 and 597 cm⁻¹ are due to Bi-O and I-O bond and the broad band at 3476 and 1628 cm⁻¹ corresponds to the stretching and bending vibration modes of the O-H bond for the water molecules adsorbed on the surface (Bavani et al. 2021). For NiMoO₄, the band located at 471 cm⁻¹ is associated with Mo-O-Mo bond and the peak present at 863 and 1092 cm⁻¹ are the asymmetric and symmetric stretching vibrations of the Mo = O linkage. The Mo-O-Ni band at 722 cm⁻¹ and the bending and stretching vibrations of O-H are placed at 1616 and 3416 cm⁻¹ (Mengting et al. 2020). As for composites, it is noticed that the peaks of both NiMoO₄ and BiOI are seen in NiMoO₄/BiOI nanocomposites and the peak intensities of NiMoO₄ seems to be increasing with the increasing amounts of NiMoO₄ in BiOI, thus clearly showing the formation of the NiMoO₄/BiOI nanocomposite between the BiOI and NiMoO₄.

TEM analysis clearly provides the details on the insights of the morphology and crystalline structure of the photocatalysts. Figure 3 shows the TEM and HR-TEM images of the pure BiOI, pure NiMoO₄ and the optimized NMBI-1 nanocomposite photocatalyst. While, Fig. 3a shows the a nanoplate like structure of the 2D-BiOI and the nanorod like morphology of the 1D-NiMoO₄ is presented in the Fig. 3b. In the case of optimized NMBI-1 nanocomposite, the NiMoO₄ nanorods are irregularly arranged on the surface of the BiOI nanoplate, which confirms the formation of the 1D/2D-NiMoO₄/BiOI nanocomposite (Fig. 3c). Here, the Fig. 3d-e shows the high magnification images of TEM (HR-TEM) and SAED pattern of NMBI-1 nanocomposite. The lattice fringes values of 0.253 and 0.295 nm corresponds to (001) and (102) planes of NiMoO₄ and BiOI respectively. Further the energy dispersive X-ray spectrum (EDAX) provides the information about the elements present in the NMBI-1 nanocomposite (Fig. 4a). As seen in Fig. 4a, Bi, Ni, Mo, I and O are present in the NMBI-1 nanocomposite, here both the elements of the BiOI and NiMoO₄ are present and it confirms the absence of other impurities are noticed in the composite which exposes the purity of the synthesized photocatalyst. Additionally, Fig. 4b displays the elemental mapping images of the optimized NMBI-1 nanocomposite that clearly shows the presence of the Bi, Ni, I, Mo and O elements in the composite. Moreover, the EDAX and elemental mapping studies confirms the formation of the NiMoO₄/BiOI composite between NiMoO₄ and BiOI without any impurities.

The optical characteristics of the photocatalysts were investigated by UV- visible diffuse reflectance spectroscopy (UV- DRS) and photoluminescence (PL) analysis. Figure 5a displays the UV-vis DRS of the as-prepared photocatalysts and the band gap energy (E_g) values of the photocatalysts that are calculated using Kubelka-Munk function as given in Eq. (1) (Priya et al. 2018)

$$\alpha h\nu = A (h\nu - E_g)^{n/2} \quad (1)$$

Here, α , h , ν , A , E_g and n are the absorption coefficient, Plank's constant, light frequency, proportionality constant, bandgap energy value and nature of transition respectively. From Fig. 5b, the E_g values are calculated in accordance to $(\alpha h\nu)^{1/2}$ Vs $h\nu$ plot and are given as 1.94, 2.43, 1.64, 1.78, 1.85 eV that corresponds to pure BiOI, pure NiMoO₄, NMBI-1, NMBI-2, NMBI-3, NMBI-4 nanocomposite photocatalysts. Here, the E_g values of different NiMoO₄/BiOI nanocomposites are noted to be comparatively lower than both the pure BiOI and NiMoO₄. Whereas, the E_g values of the NiMoO₄/BiOI nanocomposites seem to gradually increase by the addition of NiMoO₄ to pure BiOI. The lower E_g values of NiMoO₄/BiOI nanocomposite photocatalysts indicates higher absorption in the visible region as well as higher photocatalytic activity by reducing the rapid rejoining of the photogenerated e^-/h^+ .

Photoluminescence (PL) spectrum discloses the transfer and separation ability of the photoexcited charge carriers on the surface of the semiconductor. Figure 6 is the PL spectrum of pure BiOI, pure NiMoO₄ and different NiMoO₄/BiOI nanocomposite photocatalysts at excitation wavelength of 320 nm. As seen in Fig. 6, the different NiMoO₄/BiOI nanocomposite photocatalysts delivers relatively lower PL emission peak intensity compared to pure BiOI and NiMoO₄. This inferred that NiMoO₄/BiOI nanocomposites exhibits the lower recombination of charge carriers, as it accelerates the charge transfer and separation efficiency and favors the enhanced photocatalytic performance. Similarly, the higher PL emission peak intensity directs greater reconnection of the charge carriers. As observed, the PL intensity shows a decreasing trend NMBI-1 > NMBI-2 > NMBI-3 > BiOI > NiMoO₄. Herein, the 1 wt % of NiMoO₄ in the BiOI shows a lesser PL emission, so it is expected to show greater photocatalytic degradation performance towards MB.

3.1. Photoelectrochemical performance

The photoelectrochemical performance delivers the charge transfer and separation efficiency of the e^-/h^+ pairs. Figure 7 displays the transient photocurrent response and Nyquist plot for the pure BiOI, pure NiMoO₄ and optimized NMBI-1 nanocomposite photocatalyst. Here, the optimized NMBI-1 nanocomposite has higher photocurrent response than the pure BiOI and NiMoO₄, which reveals the higher separation and lower reconnection of e^-h^+ pairs. The transfer and separation of the charge carriers are further investigated by the electrochemical impedance spectrum (EIS) as shown in Fig. 7a. From the Fig. 7b, the optimized NMBI-1 heterostructure exhibits smaller semicircular diameter than BiOI and NiMoO₄, which reflects in lower charge transfer resistance and also assumed to reduce the rapid rejoining of the e^-/h^+ pairs. Hence, the optimized NMBI-1 heterostructure has higher separation and

reduced recombination of the charge carriers and is expected to show superior photocatalytic performance.

3.2. Photocatalytic performances

Under illumination of visible light, the photocatalytic performance of the as-synthesized photocatalysts are explored to evaluate against the degradation of MB. The Fig. 8a presents the photocatalytic degradation plots of pure BiOI, pure NiMoO₄ and NiMoO₄/BiOI nanocomposite. As noticed, there is no notable change observed in the self-degradation of MB. On the other hand, as shown in Fig. 8b, the NiMoO₄/BiOI (NMBI-1, 2 and 3) nanocomposites has a significant improvement in the photocatalytic degradation (92.7, 66 and 45.5%) than the pure BiOI (40.7%) and NiMoO₄ (25.8%). In the series of NiMoO₄/BiOI composites, the 1 wt% of NiMoO₄ in BiOI (NMBI-1) displayed a maximum photocatalytic ability towards MB degradation. This is due to the lower band gap that led to the effective absorption in the visible region and the nanocomposite formation between the semiconductors. This is expected to reduce the rapid reconnection and increased transfer and separation efficiency of e⁻-h⁺ pairs. However, the photocatalytic activity of the NiMoO₄/BiOI composites decreased above the addition of 1 wt% due to excessive NiMoO₄ on the surface of the BiOI. Thus, the photocatalytic degradation performance decreased in the following manner as NMBI-1 > NMBI-2 > NMBI-3 > BiOI > NiMoO₄.

As observed in Fig. 8c, the photocatalytic activity of NiMoO₄/BiOI composites towards MB degradation follows the pseudo first order kinetics as expressed using the following equation (Priya et al. 2020).

$$\ln(C_0/C) = kt \quad (2)$$

Where, k is the rate constant, t is the irradiation time (min) and C₀ and C are the concentration at initial and different time intervals. Figure 8c displays the rate constant values of all the as-prepared photocatalysts. The rate constant value for NMBI-1 is 0.0442 min⁻¹ and found to be around 12 and 5 times higher than the pure NiMoO₄ and BiOI respectively. This represents that there is a formation of NiMoO₄/BiOI nanocomposite between NiMoO₄ and BiOI, which considerably increases the separation of the e⁻-h⁺ pairs.

In the view of practical execution, it is essential to study the influence of catalyst dosage, reusability and stability nature of the photocatalyst. Figure 8d shows the effect of NMBI-1 catalyst dosage on the degradation of MB, by using different catalyst amount of 0.5, 0.1, 1.5 and 0.2 gL⁻¹. The increasing photodegradation performance is noted till 1.0 gL⁻¹ of catalyst, after which a decrease in dye degradation is noted. This is mainly attributed to the formation of turbidity in the high dosage of catalyst, that led to the scattering of light. Apart from this, the reusability and stability are the most important factors for large-scale operations. Hence, at the end of every cycle, the photocatalyst was collected by centrifugation and dried at 80 °C for 3 h and then reintroduced in the next cycle. Figure 9a demonstrates the reusability and photostability characteristics of NMBI-1 nanocomposite, as it reveals the high catalytic stability after four cycles, thus proving the optimized NMBI-1 composite as a potential material

for the remediation of wastewater. However, Fig. 9b, shows no significant change in the XRD pattern of NMBI-1 before and after recycling tests. These results too supported the stable nature of the synthesized photocatalyst material.

Besides the stability, major active species in the photocatalytic degradation of MB using the optimized NMBI-1 composite is studied by the radical trapping experiments. Various, radical trapping agents namely, benzoquinone (BQ, 1mM), ammonium oxalate (AO, 1mM), isopropyl alcohol (IPA, 1mM) are used to suppress the $O_2^{\cdot-}$, h^+ , $\cdot OH$ radicals respectively (Priya et al. 2018). As in Fig. 9b, no notable effect in photodegradation is observed using BQ which indicates the $O_2^{\cdot-}$ is not an active species in the degradation of MB. Meanwhile, the degradation efficiency is found to considerably decreased on adding of AO and IPA revealing the active role of $\cdot OH$ and h^+ in the degradation of MB.

3.3. Photocatalytic degradation mechanism

The conduction band (CB) and valence band (VB) potentials of the photocatalysts were calculated by using the following Eqs. (3) and (4), (Senthil et al. 2021)

$$E_{VB} = X - E_e + 0.5 E_g \quad (3)$$

$$E_{CB} = E_{VB} - E_g \quad (4)$$

Where, E_{VB} and E_{CB} are the valence band and conduction band potentials respectively. Here, E_g , E_e and X are band gap energy value, energy of free electrons (4.5 eV) and electronegativity of the photocatalyst respectively. The electronegativity of the pure BiOI and pure $NiMoO_4$ are 5.936 and 6.176 eV respectively. Based on the above equation, the calculated E_{CB} and E_{VB} values of BiOI nanoplate are 0.471 and 2.40 eV respectively. Additionally, the E_{CB} and E_{VB} values of $NiMoO_4$ nanorods are 0.461 and 2.89 eV respectively.

According to the mechanism explained, both BiOI and $NiMoO_4$ are get excited under VLI and produce holes and electrons on the CB and VB correspondingly. The e^- on the CB level of $NiMoO_4$ moves towards the corresponding level of BiOI and similarly the h^+ on the VB level of the $NiMoO_4$ migrates to the respective level of the BiOI. Thus, photoproduced e^- and h^+ are effectively separated and easily transferred in the well fabricated interface of the 1D/2D- $NiMoO_4$ /BiOI nanocomposite, thereby, reducing the rapid rejoining of the e^-/h^+ pairs to increase the photocatalytic degradation activity of MB under VLI. On the basis of obtained results, the possible charge transfer mechanism for the degradation of MB using 1D/2D- $NiMoO_4$ /BiOI nanocomposite under VLI is displayed in Fig. 10. The results are found to disclose the fabricated 1D/2D- $NiMoO_4$ /BiOI nanocomposite photocatalyst as a potential material to be used for wastewater treatment applications.

4. Conclusions

Low-cost and visible light active 1D/2D-NiMoO₄/BiOI nanocomposite was fabricated by single step solvothermal synthesis method. The 1D/2D-NiMoO₄/BiOI nanocomposite has proved its effectiveness by increasing the photocatalytic degradation efficiency. Herein, the 1 wt % of NiMoO₄ in BiOI (NMBI-1) photocatalyst showed the highest photodegradation efficiency among the different NiMoO₄/BiOI composites and pure NiMoO₄, BiOI photocatalysts. The photoelectrochemical and PL studies displayed by the optimized NMBI-1 nanocomposite had the lower reconnection of e⁻/h⁺ pairs, and also exhibited the excellent photostability and reusability properties. Here, h⁺ and ⁻OH played a major role in the degradation of MB under VLI. Moreover, the formation of the 1D/2D-NiMoO₄/BiOI nanocomposite between the 1D-NiMoO₄ and 2D-BiOI assist to promote the charge carriers through their interfaces, thereby reducing their recombination, thereby effectively increased the photocatalytic degradation efficiency under VLI. On the basis of above results, the 1D/2D-NiMoO₄/BiOI nanocomposite photocatalyst can be considered as a potential material for the remediation of wastewater.

Declarations

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Authors Contributions

All authors contributed to the study conception and design. Material preparation, data collection, analysis and the first draft of the manuscript was written by Thirungnanam Bavani. Supervision, validation, writing – review & editing by Jagannathan Madhavan. Visualization by Sepperumal Murugesan and Manickam Selvaraj. Validation, investigation conducted by Vasudevan Vinesh and Bernaurdshaw Neppolian, *and all*

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Figures

Figure 1

Pictorial outline for the synthesis of 1D/2D- $\text{NiMoO}_4/\text{BiOI}$ nanocomposite photocatalyst.

Figure 2

(a) XRD patterns and (b) FT-IR of (a-e) pure NiMoO_4 , pure BiOI and $\text{NiMoO}_4/\text{BiOI}$ nanocomposites photocatalysts.

Figure 3

(a), (b) and (c) are TEM images of pure BiOI , pure NiMoO_4 and NMBI-1 nanocomposite photocatalyst, (d) and (e) are HR-TEM and SAED pattern of NMBI-1 nanocomposite photocatalyst.

Figure 4

(a) and (b) are the EDAX and elemental mapping images of the NMBI-1 nanocomposite photocatalyst.

Figure 5

(a) UV-vis DRS and (b) Kubelka-Munk plot of pure BiOI, pure NiMoO₄ and NiMoO₄/BiOI nanocomposite photocatalysts.

Figure 6

Photoluminescence spectra of pure BiOI, pure NiMoO₄ and different NiMoO₄/BiOI nanocomposites.

Figure 7

(a) Transient photocurrent response and (b) Nyquist plots of pure NiMoO₄, pure BiOI and NMBI-1 nanocomposite photocatalyst.

Figure 8

(a) Photodegradation and (b) pseudo first-order kinetics plot and (c) the rate constant values towards the degradation MB over pure BiOI, pure NiMoO₄ and different NiMoO₄/BiOI nanocomposites. (d) Influence of catalyst amount on the removal of MB over NMBI-1 nanocomposite.

Figure 9

(a) Recycling runs and (b) Radical trapping of NMBI-1 nanocomposite photocatalyst towards the degradation of MB under VLI. (c) XRD pattern of the NMBI-1 nanocomposite photocatalyst before and after recycling test.

Figure 10

Schematic representation of the plausible charge transfer mechanism of the 1D/2D-NiMoO₄/BiOI nanocomposite towards the degradation of MB under visible light.