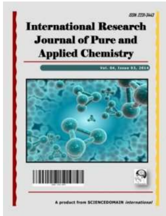

International Research Journal of Pure & Applied Chemistry

14(2): 1-6, 2017; Article no.IRJPAC.34828
ISSN: 2231-3443, NLM ID: 101647669

Photocatalytic Degradation of Carbon Monoxide (CO) Using Bi_2O_3 Modified TiO_2 Photocatalyst

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Authors' contributions

This work was carried out in collaboration between all authors. Authors NI and AR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AR and SJP managed the analyses of the study. Authors AR and AKC managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IRJPAC/2017/34828
Editor(s):
(1) Francisco Marquez-Linares, Full Professor of Chemistry, Nanomaterials Research Group, School of Science and Technology, University of Turabo, USA.
Reviewers:
(1) Ashish Kumar, Agra College, India.
(2) Anukorn Phuruangrat, Prince of Songkla University, Thailand.
(3) Tariq Mahmood, Quaid-i-Azam University, Pakistan.
Complete Peer review History: http://www.sciencedomain.org/review-history/20011

Original Research Article

Received 14th June 2017
Accepted 10th July 2017
Published 12th July 2017

ABSTRACT

TiO_2 modified Bi_2O_3 nanoheterojunction was prepared using maleic acid as an organic linker. TiO_2 phatocatalyst cannot perform photocatalytic reaction in the visible region. It only can work in the UV light region because of its band gap 3.2 eV. On the other hand Bi_2O_3 modified TiO_2 can perform photo activity in UV as well as visible region because Bi_2O_3 can absorb photon in the visible light. The Bi_2O_3/TiO_2 nanocomposite was characterized Transmission Electron Microscope (TEM), X-ray diffraction (XRD), UV-Vis spectroscopy and Gas Chromatography (GC). The as modified composite exhibited high photo oxidation activity under visible region of λ up to 430 nm, whereof the modified photocatalyst can oxidize CO in UV as well as visible light. Because of the development of anti-air pollution technology, our modified nanoheterojunction could be a significant photocatalyst to oxidize pollutants in air to keep the environment clean.

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Keywords: Photo oxidation; Bi_2O_3/TiO_2 nanocomposite; carbon monoxide (CO); air pollution.

1. INTRODUCTION

In recent years photocatalytic oxidation (PCO) is widely studied in the field of water and air pollution control to clean-up the environmental hazardous pollutants [1-5]. The research on oxidation of carbon monoxide (CO) has become an important topic during the last few years. CO is a harmful air pollutant for the living environment and generally it produce in partial combustion of hydrocarbons. Photocatalytic oxidation process is one of the most promising resolutions to decompose CO. Especially TiO_2 phatocatalyst can successfully degrade the volatile organic compounds present in air under normal temperature [6-9]. However, the limitation is TiO_2 only can work under UV light because of its large band gap of 3.2 eV [10]. Therefore, modification of TiO_2 is mandatory to absorb visible light in the photocatalytic process to enhance the reaction rate.

There are different ways to modify TiO_2 phatocatalyst. Among them doping by metal and non-metal, photosensitizing with dye on TiO_2 surface, modification by semiconductors having narrow bandgap and noble metal depositions are widely used. Of the many processes modification of TiO_2 using noble metal deposition on its surface have recently been placed as one of the most feasible modification process for enhancing the photocatalytic oxidation reactions [11-13].

In this research, TiO_2 was modified by bismuth (III) oxide (Bi_2O_3) to enhance the photocatalytic activity of TiO_2. Maleic acid was used as an organic linker to develop the Bi_2O_3/TiO_2 nanoheterojunction. The presence of Bi_2O_3 on TiO_2 surface significantly enhances the photocatalytic oxidation rate of CO because the PCO reaction can possible in presence of UV as well as visible light [14]. On the other hand, research literatures have confirmed that Bi_2O_3 is comparatively cheap and less toxic than other metals like led, iron and antimony [10,14].

2. EXPERIMENTAL

Carbon Monoxide (CO), titanium dioxide (TiO2) nanoparticle, bismuth oxide (Bi2O3), maleic acid (C4H4O4) and absolute ethanol (CH3CH2OH) were purchased from Sigma Aldrich (Germany) and were used without further purification.

2.1 Modification of TiO_2 with Bi_2O_3

Different molar ratios of Bi_2O_3 modified TiO_2 were prepared using maleic as an organic linker. 5/95, Bi_2O_3/TiO_2 was synthesized using 5 mol% of Bi2O3 and 95 mole% of TiO_2. During synthesize process 0.24 g of Bi_2O_3 was dissolved in 50 mL of ethanol solution. Then 0.2 g of maleic acid was added in to the solution. Afterward, 0.76 g of TiO_2 was added in to the mixture and stirred for 5 h at room temperature until a homogenous solution. Then the suspension was stand in an oven for overnight at 60℃ for drying. To increase the bonding between TiO_2 and Bi_2O_3 the prepared composite was annealed at 120℃ in a muffle furnace. The same methodology was used to synthesize at ratios of 20/80, 35/65, 50/50, 65/35, Bi_2O_3/TiO_2 nanoheterojunction [14].

2.2 Photocatalytic Oxidation Test

Photocatalytic oxidation of CO was carried out in a gas reactor prepared in the laboratory. Gas chromatography (GC) was used to measure the remnant of CO after photocatalytic oxidation reaction. Our modified phatocatalyst was placed inside the gas reactor and the light source was placed in front of the phatocatalyst. The CO gas was inserted in to the gas reactor and after oxidation the remnant of CO was collected and was analyzed using GC.

2.3 Characterization Techniques

The surface structure of the pure and modified TiO_2 were observed using fei-TECNAI G2 Transmission Electron Microscopy (TEM). A D8 Bruker Advance X-ray diffractometer (Bruker, Germany) was used to analyze the X-ray diffraction measurements. A Shimazu UV-1601 spectrophotometer was used to record UV-Vis reflectance spectra. To observe the photocatalytic oxidation rate of CO a Gas Chromatograph was used with the gas reactor.

3. RESULTS AND DISCUSSION

3.1 Crystallite Shape and Compositional Analysis

In Fig. 1 the surface morphology of 65/35, TiO_2/Bi_2O_3 nanocomposite was analyzed using transmission electron microscope (TEM) and high resolution electron microscopy (HR-TEM).

The crystallite structure of TiO_2 nanoparticles can be clearly noticed from Fig. 1(a-b). In Fig. 1(c-d) the modification of TiO2 using Bi_2O_3 was observed. Thus, the TEM analysis asserts that the Bi_2O_3 was finely distributed on the TiO_2 surface and no other unwanted particles observed.

The Energy-dispersive X-ray spectroscopy (EDX) elemental analysis was performed on Bi_2O_3 modified TiO_2 nanocomposite in a weight ratio of TiO_2:Bi_2O_3; 65:35 which shown in Table 1. From the analysis, it is clear that at the end of the modification process the rest of the maleic acid was evaporated from the nanocomposite. Only Ti, Bi and O elements were found from the analysis that represent the presence of TiO_2 and Bi_2O_3 in the nanocomposite.

Table 1. EDX data of Bi_2O_3 modified TiO_2 nanocomposite

Elements	Bi_2O_3 modified TiO_2 nanocomposite Wt.%
Ti	41.56
Bi	4.08
O	54.36

(Weight ratio of TiO_2:Bi_2O_3; 65:35)

3.2 XRD Analysis

The XRD patterns of TiO_2, Bi_2O_3 and Bi_2O_3 modified TiO_2 nanocomposite is presented in Fig. 2. The TiO_2 nanoparticle curve showed peaks at 25.3°, 37.8°, 54°, and 62.10°, which indicate the present of the anatase phase and at 43.90°, 56.90°, and 65.10°, exhibited the rutile phase. The Bi_2O_3 curve also exhibited some diffraction peaks at 21.90°, 26.90°, 32.80°, 47.19°, and 55.20°. The XRD patterns of Bi $_2O_3$ modified TiO_2 nanocomposite equalized the diffraction peaks of TiO_2 and Bi_2O_3 without added of any other compounds phases. This observation declares that in the composite formation process no other chemical reactions occur between Bi_2O_3 and TiO_2 nanoparticle.

3.3 UV-Vis Analysis

The UV-vis absorption spectra of TiO_2, Bi_2O_3 and the different ratios of Bi_2O_3/TiO_2 nanocomposite are illustrated in Fig. 3. The bandgap of TiO_2 is wide than Bi_2O_3 and were investigated to be 3.2 eV and 2.8 eV, respectively [15,16]. The optical absorptions of Bi_2O_3 is greater than of 400 nm and for that reason Bi_2O_3 can absorb the photon from the visible light of the solar spectrum. TiO_2 optical absorption is less than 385 nm therefore, TiO_2 is photo inactive in the visible light. On the other hand, the optical absorption of Bi_2O_3 modified TiO_2 nanocomposites are greater than 400 nm because of the presence of Bi_2O_3. The photon absorption rate in the visible light increase with the increasing of the molar percentage of Bi_2O_3 in the composite. This analysis demonstrate that Bi_2O_3/TiO_2 nanoheterojunction is effective for the photon absorption in the visible light.

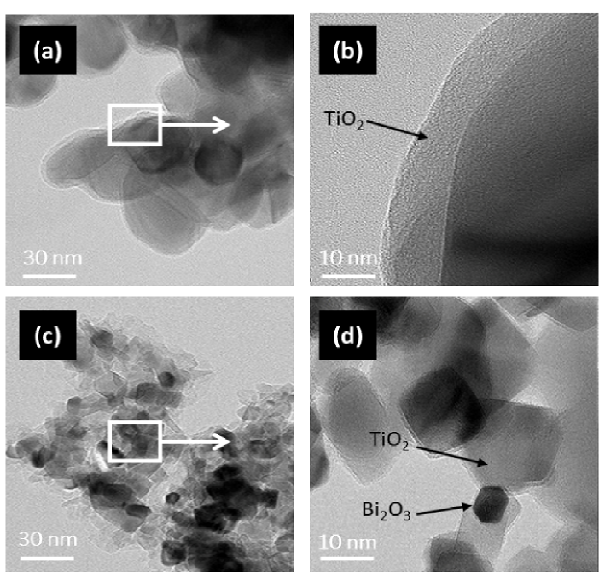

Fig. 1. TEM images of (a, b) pure TiO_2 nanoparticle (c, d) Bi_2O_3 modified TiO_2 nanocomposite

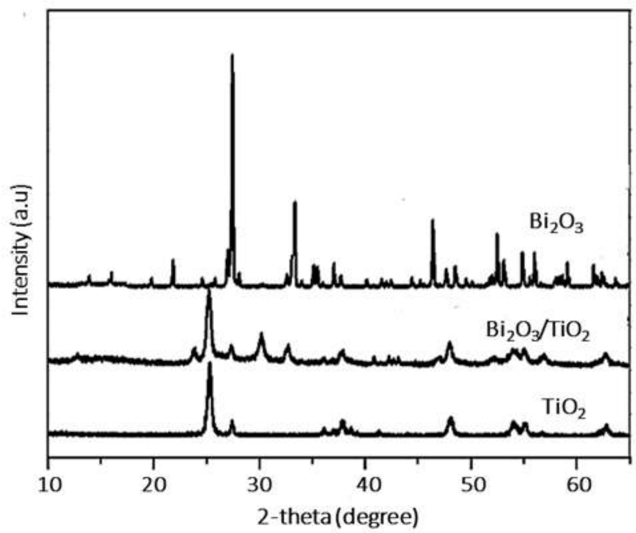

Fig. 2. XRD analysis of TiO_2, Bi_2O_3 and Bi_2O_3 modified TiO_2 nanocomposite

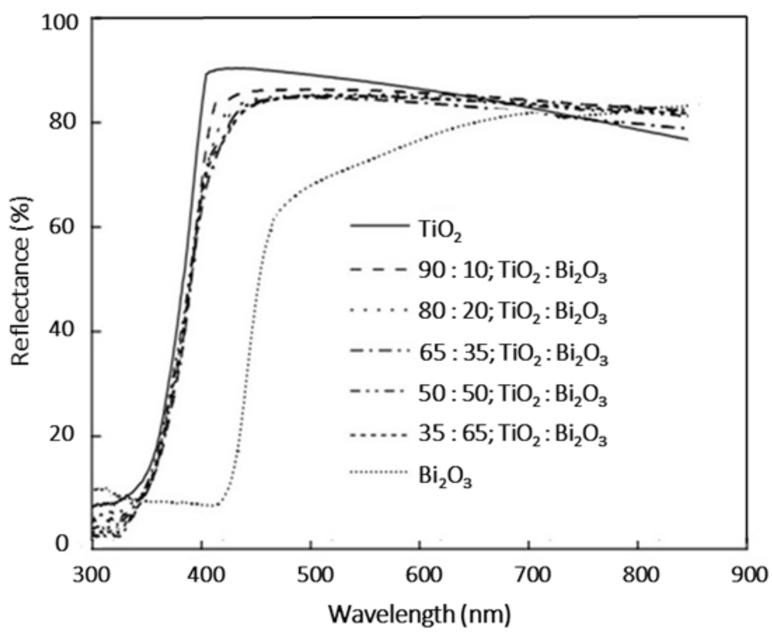

Fig. 3. UV-vis absorption spectra of TiO_2, Bi_2O_3 and different ratios of Bi_2O_3 modified TiO_2 nanocomposite

3.4 Photocatalytic Oxidation of CO

Fig. 4 illustrate the photocatalytic oxidation of CO on pure TiO_2 and Bi_2O_3 modified TiO_2 under visible light. In case of pure TiO_2 no photo oxidation occurs because TiO_2 cannot absorb photon in the visible light. The different ratios of Bi_2O_3/TiO_2 composites perform different photocatalytic activity. With increasing the percentage of Bi_2O_3 in the composite the rate of oxidation also increase but 65/35, TiO_2/Bi_2O_3 exhibited highest photo oxidation of CO.

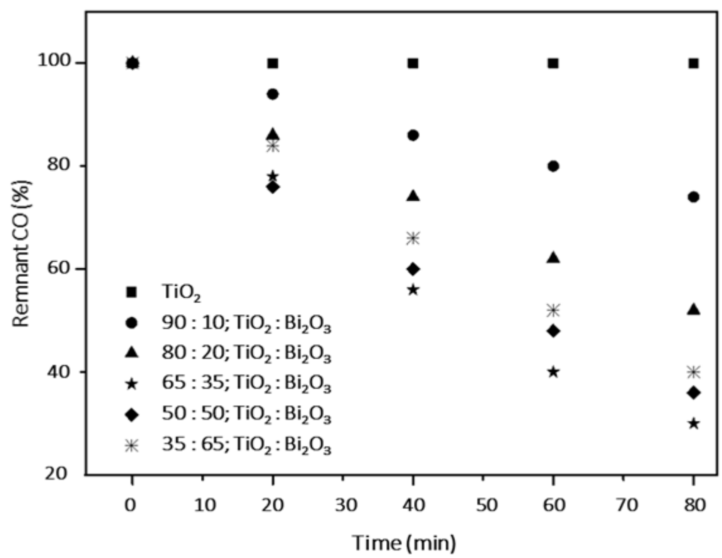

Fig. 4. Remnant CO after photocatalytic oxidation of CO on TiO_2, and different ratios of Bi_2O_3 modified TiO_2 nanocomposites

4. CONCLUSION

Bi_2O_3 modified TiO_2 phatocatalyst was prepared using maleic acid as an organic linker. The Bi_2O_3 has finely distributed on the TiO_2 nanoheterojunction. The Bi_2O_3/TiO_2 composite successfully performed photocatalytic oxidation of CO in the visible light region. The role of Bi_2O_3 in the composite was to absorb the photon from the visible region and to be active of the Bi_2O_3/TiO_2 nanoheterojunction for the photo oxidation of CO in the UV as well as visible light.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20011