Incorporation of $BiVO_4$ into Mesocellular SiO_2 for Application in Photodegradation of Emerging Pollutants

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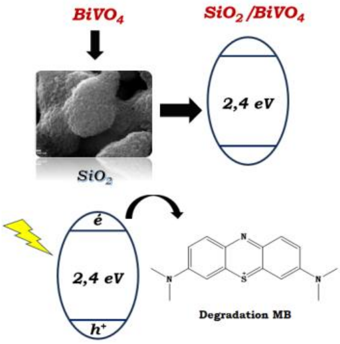


The bismuth vanadate ($BiVO_4$) is a promising material for application in environmental remediation processes employing heterogeneous photocatalysis. In this study, a series of new $SiO_2/BiVO_4$ composites were obtained using mesocellular silica and solvothermal synthesis for $BiVO_4$ deposition. The materials were characterized by XRF, XRD, FTIR, SEM and their photocatalytic activity was monitored by UV-Vis using methylene blue as a model pollutant. The materials exhibited interesting photocatalytic activity with the SV4 composite showing a removal rate of 75% in 60 minutes of irradiation. These observations open up possibilities for the preparation of supported $BiVO_4$ photocatalysts for environmental applications.

Introduction

Heterogeneous photocatalysis is a sustainable and promising alternative for environmental remediation processes [1]. The use of semiconductor materials activated in the presence of radiation makes it possible to reduce the concentrations of contaminants such as drugs, pesticides and dyes in polluted aquatic systems. Photocatalysts based on SiO_2/TiO_2 [2], ZnO [3] and $BiVO_4$ [4] show good efficiency in photodegradation processes, leading to the conversion of contaminants into species with a lower degree of toxicity. Among the possibilities described, $BiVO_4$ has received great attention, as the material with a monoclinic crystalline structure (bandgap 2.34 eV) presents good photocatalytic activity in the visible light region due to the formation of oxidative species with high redox potential. In this sense, $BiVO_4$ differs from several photocatalysts documented in the literature that lack activity under visible light, making it possible to use sunlight to activate this material as a photocatalyst [4]. The incorporation of the oxide into support materials is interesting, as it makes it possible to obtain materials with greater photocatalytic efficiency, compared to the isolated material. Given the challenge of recovering nanomaterials in photodegradation processes, the incorporation of these structures into larger porous supports, such as SiO_2, can significantly facilitate this process [5]. Thus, there is interest in incorporating the component into mesocellular silica structures, in order to evaluate the efficiency of the system against the degradation of the methylene blue (MB) dye.

Material and Methods

The mesocellular silica was obtained using the route proposed by Schmidt – Winkel et al [5]. The $SiO_2/BiVO_4$ composites were prepared in different proportions (w/w = 5%, 10%, 15%, 25%, and 40% relative to $BiVO_4$) by reacting SiO_2 with a solution of $Bi(NO_3)_3{\cdot}5H_2O$ and NH_4VO_3 dispersed in ethanol and water. After stirring, the solution was subjected to solvothermal treatment at 160°C for 24 hours for crystallization. The obtained solids were washed with water and dried at 80°C. The materials were analyzed by X-ray diffraction (XRD) to determine the crystalline structure, scanning at 2θ with and interval between 10° and 100°. Fourier transform infrared spectroscopy (FTIR) spectra (4000 – 600 cm^{-1}) were employing an attenuated total reflection. The composition of the materials was evaluated by X-ray fluorescence spectroscopy (XRF) to determine the percentage of components present in the samples.
The morphology analysis was carried out by scanning electron microscopy. Evaluation of the photocatalytic performance of the prepared materials (200 mg L^{-1}) for the removal of 60 mL methylene blue (7,5 mg L^{-1}) was performed using a Hg lamp, a borosilicate glass photoreactor distance at 8 cm. The pollutant concentrations were measured by collecting sample aliquots from the reactor outlet at different time intervals during the initial 30 min in the dark and afterward under continuous illumination.

Results and Discussion

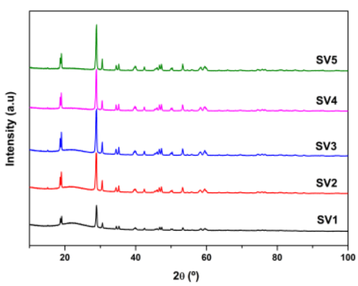
XRF data was obtained in order to compare the composition of the samples. The results indicate an almost linear pattern between the decrease in SiO_2 content as the $BiVO_4$ concentration increases, as expected. The data are present in table 1.

Table 1. Data XRF for composites obtained.

Sample	%$BiVO_4$	%SiO_2 (XRF)
SV1	5	98,2
SV2	10	80,7
SV3	15	84,7
SV4	25	68,6
SV5	40	53,0

Figure 1 shows the XRD of the samples. In diffractograms it is possible to see peaks that correspond to the monoclinic crystal structure of $BiVO_4$. Around 25° a non-crystalline portion is observed referring to the SiO_2 present.

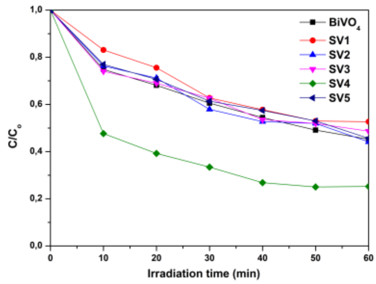
Figure 1. XRD of composites SiO_2/$BiVO_4$



The FTIR spectra of the materials confirmed the presence of the oxide components in the composites. The band around 1100 cm^{-1} corresponds to the asymmetric stretching of Si-O-Si bonds.

The SEM images confirm the coverage of the SiO_2 mesopores with bismuth vanadate crystals. The photodegradation curves of the SiO_2/$BiVO_4$ materials obtained, as well as bare $BiVO_4$ are shown in Figure 2. It is observed that among the materials obtained, the one containing 25% $BiVO_4$ is the one with the best photocatalytic efficiency against the degradation of methylene blue. The other composites, as well as bare $BiVO_4$, present similar and lower photocatalytic activity. Thus, prepared SV4 composite is the most promising in environmental remediation applications.

Figure 2. Photodegradation curves for composites.



Conclusions

In this study, a series of composites containing SiO_2/$BiVO_4$ were prepared using mesoporous silica as a support material. The incorporation of the photocatalytic component in the proportion of 25% by mass, exhibits good activity compared to unsupported $BiVO_4$, displaying 75% degradation of methylene blue after 60 minutes of exposure to UV-vis radiation.

Acknowledgments

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