Brown TiO_2 Structured Catalyst Supported on SiC for Ethanol Photo-Reform using Visible Light

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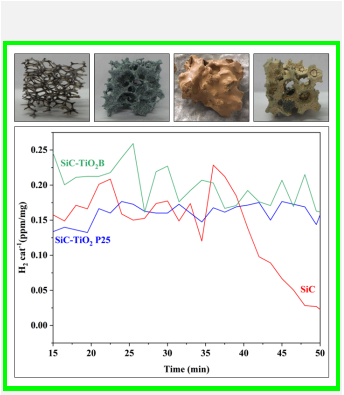

Titanium dioxide (TiO_2) is widely used as a photocatalyst but must be suspended within the reaction system to enhance efficiency. However, this could result in problems in the environment since the catalyst can only be used once or requires several separation steps afterward. To overcome this problem, TiO_2 is combined with other semiconductors on a suitable support, which, together with TiO_2, could improve its material photocatalyst characteristics. Due to the properties offered, silicon carbide (SiC) foam ceramics have been considered an attractive substrate for TiO_2, regarding the bandgap reduction and improved material adsorption in visible light. A photo-reform of an ethanol-water system was applied to produce hydrogen through a homemade semi batch reactor and measured with the aid of an MQ-8 sensor

Introduction

Nowadays, photo-reforming ethanol presents an attractive choice for hydrogen production using a semiconductor and a light source [1]. To improve this process, it is necessary to develop catalysts that can be stable and efficient. TiO_2 is one of the most promising photocatalysts; it is stable, and large quantities are available at low prices [2]. However, its large bandgap resulted in photoactivity only under UV light irradiation. Besides, TiO_2 must be dispersed in the reaction system to improve its efficiency, which can cause problems with separation and loss of the catalyst. Several methods were reported to overcome these drawbacks. Coupling TiO_2 with other semiconductors and on suitable support can result in an enhanced catalytic system [3].

Silicon carbide (SiC) foam ceramics have been considered an attractive substrate for TiO_2, mainly associated with properties such as high surface area, high permeability, and low density [4]. SiC's positive role in enhancing the photocatalyst property is due to its unique photo electrical properties (bandgap value 2.39 - 3.33 eV), low thermal expansion, high strength, and good chemical and thermal stability [4].

This work aims to develop a structured photocatalyst, exploiting the synergy between two semiconductors, TiO_2 and SiC, for hydrogen production through photoreforming an ethanol-water system with visible light.

Material and Methods

Titanium (IV) isopropoxide was used as the precursor for Ti, and CTAB was used as a structural modifier to promote oxygen vacancies for synthesizing modified TiO_2. Due to its brown color, the powder was named TiO_2B. UV-Vis, DRS, and XRD characterized the powder.

Structured SiC supports were produced using the replica method employing a commercial polyurethane sponge with 20 ppi. For this purpose, a suspension was developed, and its composition was based on SiC, a vitreous frit residue, and a carboxymethyl cellulose solution. The support was heat-treated. The structured support was characterized by XRD, and its mechanical properties were evaluated.

To impregnate TiO_2B on the support, a suspension was prepared with the synthesized powder, ethanol, and titanium (IV) isopropoxide acting as a binder. This mixture was vigorously stirred at room temperature. The support with the best solids concentration was immersed in the mixture and then dried in an oven. A fast-firing furnace was used for 30 seconds to enhance the powder's adhesion to the support.

Catalytic tests were conducted using an experimentally developed quartz reactor. The SiC support impregnated with TiO_2B was added to an ethanol-water solution under visible light radiation. Hydrogen gas was measured using an Arduino coupled with an MQ-8 sensor.

Results and Discussion

SEM images were performed to evaluate the morphology and microstructure of support. Figure 1 (a) shows the melted glass frit caused by the heat treatment at 1000 °C when the glass bonds the SiC particles, and (b) shows TiO_2B particles distributed on the SiC support surface.

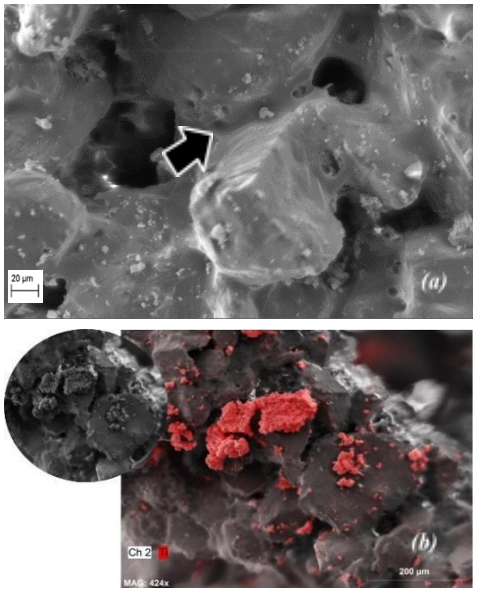

Figure 1. (a) SEM image of morphology of SiC support and (b) EDS/SEM images of TiO_2B-SiC support.

The Tauc plot (Figure 2) was used to estimate the bandgap energy of the semiconductor material and indicate whether the interaction between the catalytic powder and the support successfully decreased the bandgap energy. The lower the bandgap, the higher the photocatalytic activity under visible light irradiation.

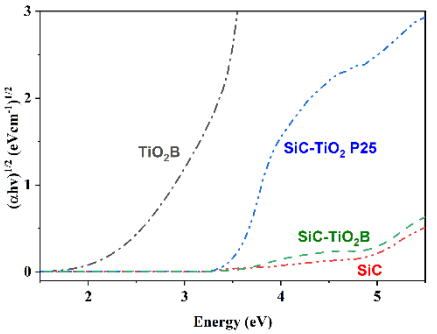

Figure 2. DRS of TiO_2B, SiC, SiC-TiO_2P25 and SiC-TiO_2B through Tauc's plot.

The ethanol-water photo-reform was performed in a semi-batch reactor. The MQ-8 sensor was calibrated and kept in air until complete stabilization, and then the reaction started. The system was maintained for 50 min and measured every 90 s (Figure 3). No data were found in the literature to compare H_2 production in these conditions.

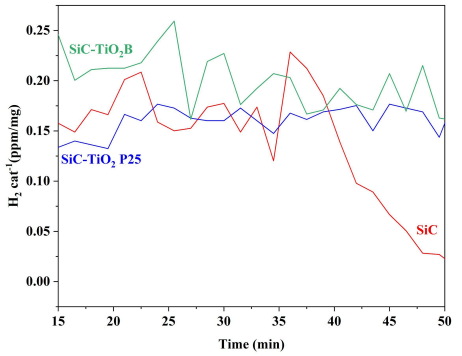

Figure 3. Photocatalytic H_2 generation under visible light conditions of SiC-TiO_2 P25 and SiC-TiO_2B.

Conclusions

The photocatalytic materials based on TiO_2 synthesized in this work present photoactivity and enhanced response; in this regard, the brown TiO_2 standalone results also indicate the possibility of its use as photocatalyst material for visible light radiation. The functionalization process herein developed, coupling dip-coating and the fast-firing methods, is appropriate to immobilize TiO_2-based photocatalysts on the support. The glass-bonded-SiC functionalized materials developed in this work can be used for photocatalytic applications, as demonstrated herein for hydrogen production.

Acknowledgments

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