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PHOTOCATALYTIC HYDROGEN PRODUCTION USING CLINOPTILOLITE-SUPPORTED, EOSIN Y-SENSITIZED TIO_2 FOR WATER SPLITTING

Jesus Marie Tumamao, Joseph Onyl Novilla, Erika Claire J. Azurin and Rizalinda L. de Leon
College of Engineering, University of the Philippines Diliman

ABSTRACT

This research aims to explore the possibility of producing hydrogen as an alternative fuel source through photocatalytic water splitting. It also seeks to synthesize a clinoptilolite-supported, Eosin Y-sensitized photocatalyst and test its activity in producing hydrogen in the visible light region. The catalyst was prepared by hydrothermal method and was characterized using thermogravimetric analysis and x-ray diffraction. Characterization showed similarities of the catalyst with those presented in literature. The catalyst was sensitized by suspending it in a diethanolamine-water solution where the Eosin Y was dissolved. This suspension was analyzed using UV-vis spectroscopy and was found to exhibit absorbance in the visible light region.

The Kubelka-Munk equation was used to determine the average band gap with a value of 2.76 eV, implying that the water splitting reaction may be successfully carried out using the catalyst. However, the gas chromatograph did not detect hydrogen under irradiation using a halogen lamp, but a positive response was obtained from a sample exposed to sunlight. For future studies, the researchers recommended improving the photocatalytic reactor setup and hydrogen collection method to achieve minimal product loss and generate more accurate results.

1. RATIONALE AND SIGNIFICANCE

Photocatalysis has also been used in the oxidation of light alkanes by Juillet and Steichner in France (Hermann, 2010). Calutech even produced a gadget for cleaning air and purifying odor with the use of photocatalytic oxidation (CaluTech, 2011). McCullagh and his group reported using photocatalysis for the disinfection of water contaminated by disease-causing microorganisms in 2007. Furthermore, Photocatalysis was used to reduce carbon dioxide to gaseous hydrocarbons in the presence of water (Tan, 2006). Kostedt et al (2005) reported that magnetic particles coated with titania particles were used to oxidize organic contaminants while being exposed to UV light.

Photocatalysis is very important in the production of hydrogen and oxygen from water because it provides the world with an environment-friendly and renewable energy source by utilizing solar energy.

This study aims to produce hydrogen from water splitting by harnessing visible light from the sun. This process can be developed as a cheaper source of clean fuel and energy, a potent replacement to carbon-containing fuels that harm the environment.

Correspondence to: Department of Chemical Engineering, College of Engineering, University of the Philippines, Diliman

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Furthermore, the processes involved in this study—zeolite support and sensitization—are not exclusive for water splitting. Thus, they can be utilized in other catalysis studies, particularly for those that use visible light from the sun.

1. OBJECTIVES

The following are the objectives of the study:

- To support TiO_2 catalyst with clinoptilolite
- To shift the sensitivity of this catalyst from the UV region to the visible light region
- To investigate the effect of calcination temperature, zeolite to TiO_2 ratio, and amount of Eosin Y added to the amount of H_2 produced

2. PROBLEM STATEMENT AND DESCRIPTION

Researches on water splitting have been advanced by the pioneering work of Honda and Fujishima in 1972. It involved the photodecomposition of water using semiconducting photoelectrolysis cells. These were composed of TiO_2 electrode and Pt black electrode connected through an external load. The TiO_2 electrode was irradiated under a small electric bias. The evolution of H_2 and O_2 occurred at the surface of the Pt electrode and TiO_2 electrode, respectively (Matsuoka, 2007).

The electrochemical splitting of water in non-irradiated conditions requires a potential difference greater than 1.23 eV between the cathode and the anode. A photon with a wavelength of around 1010 nm has energy equal to this potential difference, implying that visible light is energetically sufficient for water splitting. However, water transmits rather than absorbs visible light. It can only be decomposed under irradiation in vacuum ultraviolet light of wavelengths shorter than 190 nm (Matsuoka et al, 2007). Much research is being conducted to create visible-light responsive metal oxide photocatalysts such as titania doped with transition metal ions or oxides.

This research aims to improve titania catalyst by supporting it with zeolite and shifting the sensitivity from the UV region to the visible light region using Eosin-Y dye.

3. METHODOLOGY

The study was divided into three stages: photocatalyst synthesis, characterization and hydrogen production.

The synthesis of the photocatalyst was also divided into three parts: initial preparation of the photocatalyst using the hydrothermal method, calcination, and, finally, the incorporation of Eosin Y to the calcined photocatalyst.

The following characterization methods were employed: thermogravimetric analysis, x-ray diffraction and UV-vis spectroscopy. Thermogravimetric analysis was done to determine the calcination temperatures. X-ray diffraction results showed correspondence between the synthesized catalyst and those reported in literature. UV-vis spectroscopy was used to determine the absorbance of the photocatalyst suspended in the reaction solution of diethanolamine, water and Eosin Y. The Kubelka-Munk equation was used to evaluate the band gap energy.

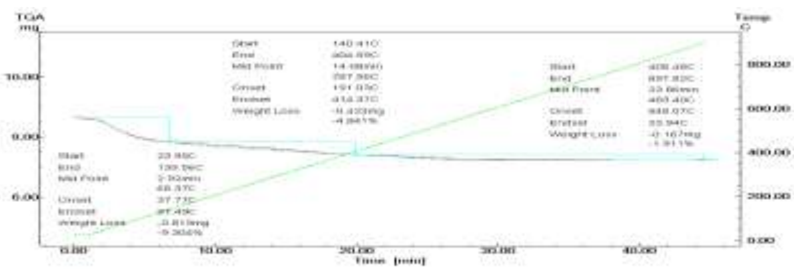
A photocatalytic reactor setup was constructed to test the activity of the synthesized catalyst. The reaction suspension which was prepared in a vacuum tube was agitated and irradiated using a 150 W halogen lamp for 4 hours. A 1-mL gas sample was collected over the suspension using a gas tight syringe. The sample was then injected into the gas chromatograph for component analysis.

4. RESULTS AND RECOMMENDATION

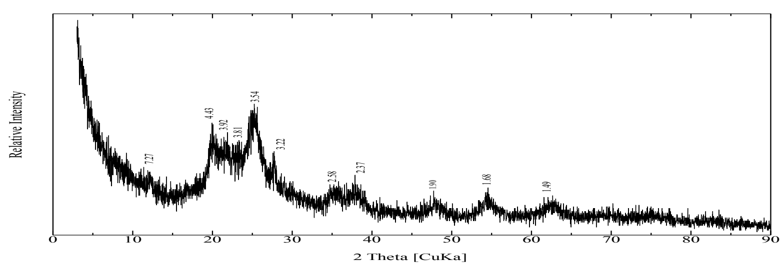
Using the Kubelka-Munk equation, the average band gap was found to be 2.76 eV, implying that the water splitting reaction may be successfully carried out using the dye-sensitized catalyst.

However, no hydrogen was detected by the gas chromatograph under irradiation using a halogen lamp, but a positive response was obtained from a sample exposed to sunlight. For future studies, the researchers recommend the improvement of the photocatalytic reactor setup and hydrogen collection method to achieve minimal product loss and generate more accurate results.

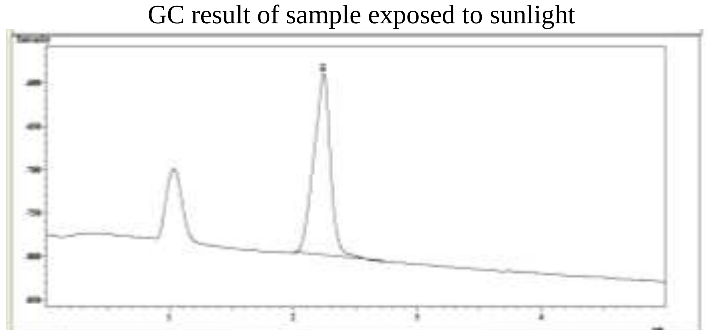
Figures



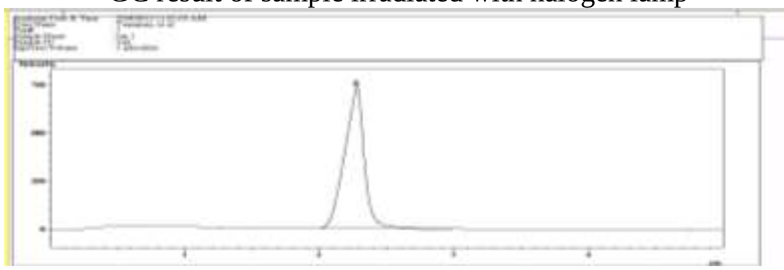
Xray Diffraction



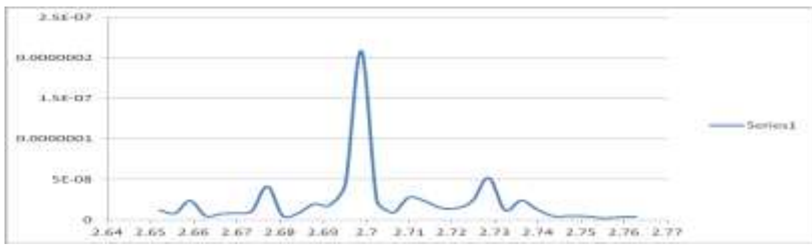
GC result of sample exposed to sunlight



GC result of sample irradiated with halogen lamp



Tauc Plot



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